Design Aspects of WINDS Ground Facility for Malaysia

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Abstract

The paper demonstrates the design aspects of Malaysian Ground Facility proposed to be established for the beam allocated at N3.14 latitude and E101.68 longitude in Ka-band by using WINDS (Wideband InterNetworking engineering test and Demonstration Satellite), which is currently under joint development, by JAXA and the National Institute of Information and Communications Technology, Japan.[8]

The purpose of the proposed ground facility is to test validity and usefulness of Ka-band technologies related to large-capacity data communications to promote the use of satellites in Malaysia for multimedia applications in such fields as Internet communications, Tele-education, Tele-medicine, Tele-networking, Tele-working, disaster measures and Intelligent Transport Systems (ITS) on non-commercial basis.[8]

I. INTRODUCTION

The function of the WINDS ground facility is to receive information from, or transmit information to, the satellite network in the most cost-effective and reliable manner while retaining the desired signal quality. Usually, the design criteria are different for the different satellites services. But a fundamental parameter in describing an earth station is the G/T. Other factors, which have an impact on earth station design and cost, are earth station EIRP, satellite tracking requirements, traffic handling capacity, interface to user or terrestrial network and network architecture, interference and compatibility analysis etc.

Further, optimization is constrained by ITU-R radio regulations and the state of technology. Making use of the unique advantage of satellite communication such as a wider coverage, broadcasting capability, and immunity to terrestrial disasters, WINDS will provide large capacity of valuable transmission media needed in our information society. Coverage includes Japan as well as Asia-Pacific regions. The satellite will carry high-gain antennas and a high-speed Asynchronous Transfer Mode (ATM) switch, enabling fast Internet access for households equipped with a small dish antenna.[8]

II. OBJECTIVES

One of the main objectives is to Carry out an experiment on Application development of e-learning by Connecting University Technical Malaysia, Malacca Campuses via WINDS system and later connecting to other participating organizations in Japan, Thailand and Malaysia. The other objectives include the development of WINDS Ground Station: for Radio Propagation Studies for Malaysia's Environment, Electromagnetic Interference and Compatibly Analysis in Ka-band. And Verification and Validation of Ka-band Technology at ultra sped data rate for Disaster Monitoring in Malaysia.

III. LITERATURE REVIEW

Ground systems design process and references discussions pertaining to each step include ground station locations, based on satellite coverage and data user needs, balanced against cost, accessibility, and available communications [1]. Link data rates, which establish the required gain-to-noise temperature ratios (G/Ts), effective isotropic radiated powers (EIRPs). Requirements for data handling and appropriate communications between ground station components and data users for dedicated station. [1][2]

To size or dimension a satellite ground station facility correctly, link budget analysis are carried out in tabular form. [5] The methodology is not very simple and also there are certain legal constraints to consider. For the analog networks, every modulation step accumulates noise form source to destination. Not so in digital network. [5][6][7]At every point of regeneration in the digital network is a point where the noise accumulation stops, and the digital signal is

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regenerated. There is digital signal regeneration in the processing satellite, but none in the bent pipe satellite.[5]

IV. METHODOLOGY

The basic data has been extracted from the WINDS documentation provided by Japan Aerospace Exploration Agency (JAXA). Optimization has been carried out by University Technical Malaysia, Malacca (UTeM)'s researchers for the purpose of achieving the desired results of the objectives using Ka-band Technology. Further link analysis has been carried out for specification of the ground terminal hardware and software.

The subsequent data is based on the results acquired by link analysis for the proposed ground facility. For link budget analysis we used the following standard equations[1][3]:

$$E_b / N_o = EIRP+L_{pr}+L_s+L_a+G_r+228.6-10\log T_s-10\log R$$

$$C / N_o = E_b / N_o +10\log R$$
$$= (EIRP) + L_s +L_a+G_r + 228.6$$

$$C/N = (EIRP) + L_s +L_a+G_r / T_s + 228.6- 10\log T_s -10\log B$$

$$G=-159.59 + 20\log D + 20\log f + 20\log \eta$$

V. DESIGN ASPECTS

SDR-VSAT (Supper high Data Rate-Very Small Aperture Terminal) and LET (Large Earth Terminal) have a TDMA (Time Domain Multiple Access) function by receiving reference burst sent from WINDS (Wideband Internetworking Engineering Test and Demonstration Satellite). [8] The proposed ground station will be operated on both modes by using electronically steer able beam antaean, +/-7 degrees in the north-south direction and +/-8 degrees in the east-west direction, which has antenna array with amplifiers and phase shifters including and Asynchronous Transfer Mode (ATM) Switching Router –a Layer-2 protocol commonly used in broadband networks. Featuring advanced QoS control to multi-media communication. [8]

The analysis demonstrates that performance parameters including EIRP and G/T of APAA (Active-phased Antenna) are less than ATM switched mode using Fixed Beam MBA (Multi-beam antenna). Subsequently larger earth stations antenna is required for APAA.For ATM base band switching mode, Data Transmission capacity in the mode depends on the performance of WINDS transponder and the performance of proposed earth station. 155 Mbps and 622 Mbps are the basic transmission rate in the WINDS network in both bent-pipe and ATM switched mode. The information for TDMA communication will be modulated by the mean of bent-pipe mode.[8]

The Design aspects of Malaysian Ground Facility aim for maximum speed of 155Mbps for downlink (receiving) / 622Mbps for uplink (transmitting) for households with 45-centimetre aperture antennas and ultra-high speed 1.2 Gbps communication for offices with five-meter antennas to be utilized for ultra speed data communication for the proposed ground terminal using WINDS satellite beam (MBA, Spot) allocated to Malaysia at N3.14 and E101.68 (Kula Lumpur) [8]. In addition to establishing a domestic ultra high speed Ground station, the proposal also aims to construct ultra high-speed international Internet access, especially with Japan, Asian Pacific countries and region that are more closely related to Malaysia.

Two types of on-board antennas will be used. One is the multi-beam antenna (MBA, Kula Lumpur Spot Beam will be used in Malacca) that enables high-speed communication through a small-sized earth station; the other is the active phased array antenna (APAA, Scanning Beam), which can establish communication link to cope with a demand of a certain area[8]. Both antennas can accommodate with on-board switching mode or Bent-pipe mode. The characteristics of equipment available are given in Table 1.

TABLE 1
EQIUPMENT CHARACTERISTICS

Earth station types	Antenna Diameter	Data rate (Mbps)
Large Earth terminal (LET)	> 5 meter	Uplink: 1.5,6,24,51,155 Downlink: 155 Uplink: 622 Downlink: 1.2Gbps
Super Data Rate-Very Small Aperture Terminal (SDR-VSAT)	2-3 meter	Uplink: 1.5,6,24,51,155 Downlink: 155
High Data Rate – Very Small Aperture Terminal (HDR-VSAT)	1-2 meter	Uplink: 1.5,6,24,51,155 Downlink:155
Ultra Small Aperture Terminal (USAT)	45 cm	Uplink: 1.5, 6 Downlink: 155

Large Earth terminal (LET) and Super Data Rate-Very Small Aperture Terminal (SDR-VSAT) can be operated at the data rate given in Table 1 by using both of the beams: Multi Beam Antenna (MBA) and Active Phase Array Antenna. MBA and APAA both can be operated in On board switching and bent-pipe modes. Whereas High Data Rate –Very Small Aperture Terminal (HDR-VSAT) and Ultra Small Aperture Terminal (USAT) can operate MBA switching mode.

VI. LINK ANALYSIS

The link budget provides the designer with values of transmitter power and antenna gains for the various links in the ground station systems is one of the key items in a space systems deign, revealing many characteristics of overall systems performance. The following tables show the link performance of the proposed ground station facility to be located in Malacca, Malaysia for WINDS System.

TABLE 2
LINK DESIGN FOR MBA2

Parameters	Uplink	Down link
Frequency	28.05 GHz	18.25 GHz
EIRP	72.6 dBW	65.2 dBW
G/T	17.7 dB/K	24.5 dB/K
EIRP	76.0dBW	80.0 dBW
Total Losses	-215.8 dB	-210.1 dB
Total C/No	103.2 dB.Hz	103.2 dB.Hz
Required E_b/N_o	7.3 dB	BER $5X10^{-4}$
Required C_b/N_o	100.2 dB.Hz	BER $5X10^{-4}$
Bit Rate	88.9 dB.Hz	782 Mbps

TABLE 3
APAA LINK DESIGN FOR 10.2 m ANTENNA SIZE OPTION-4)

Parameters	Uplink	Down link
Frequency	28.05 GHz	18.25 GHz
EIRP	81.1 dBW	54.3 dBW
Power (T_x)	17.0 dBW	-
Antenna Gain	66.3 dBi (10 .2m)	-
Slant Range	40794.7	40794.7
Total Losses	-374.4 dbW	-379.5 dBW
G/T	6.7 dB/K	36.9 dB/K
Received C/No	89.7 dB.Hz	101.4 dB.Hz
Required C/No	88.7 dB.Hz	93.9 dB.Hz
Link Margin	1.0 dB	7.5 dB
Modulation	QPSK	QPSK
Required E_b/N_o	7.3 dB (BER:5.0E-4)	7.3 dB (BER 5E-4)
Bit $Rate_o$	78.7 dB.Hz (74.0 Mb)	83.1dBHz (204 Mb)

TABLE 4
APAA LINK DESIGN FOR 4.8 m ANTENNA SIZE (OPTION-3)

Parameters	Uplink	Down link
Frequency	28.05 GHz	18.25 GHz
EIRP	81.1 dBW	54.3 dBW
Power (T_x)	23.5 dBW	-
Antenna Gain	59.7 dBi (4.8m)	-
Slant Range	40794.7	40794.7
Total Losses	-374.4 dbW	-379.5 dBW
G/T	6.7 dB/K	30.4 dB/K
Received C/No	89.7 dB.Hz	94.9 dB.Hz
Required C/No	88.7 dB.Hz	93.9 dB.Hz
Link Margin	1.0 dB	1.0 dB
Modulation	QPSK	QPSK
Required E_b/N_o	7.3 dB (BER:5.0E-4)	7.3 dB (BER 5E-4)
Bit $Rate_o$	78.7 dB.Hz (74.0 Mb)	83.1dBHz (204 Mb)

TABLE 5
APAA LINK DESIGN FOR 3.3 m ANTENNA SIZE ((OPTION-2))

Parameters	Uplink	Down link
Frequency	28.05 GHz	18.25 GHz
EIRP	71.2 dBW	54.3 dBW
Power (T_x)	17.0 dBW	-
Antenna Gain	56.3 dBi (3.3m)	-
Slant Range	40794.7	40794.7
Total Losses	-374.4 dbW	-379.5 dBW
G/T	6.7 dB/K	27.0 dB/K
Received C/No	89.7 dB.Hz	97.4 dB.Hz
Required C/No	88.7 dB.Hz	93.9 dB.Hz
Link Margin	1.0 dB	3.5 dB
Modulation	QPSK	QPSK
Required E_b/N_o	7.3 dB (BER:5.0E-4)	7.3 dB (BER 5E-4)
Bit $Rate_o$	78.7 dB.Hz (74.0 Mb)	83.1dBHz (204 Mb)

TABLE 6
APAA LINK DESIGN FOR 2.5 m ANTENNA SIZE (OPTION-1)

Parameters	Uplink	Down link
Frequency	28.05 GHz	18.25 GHz
EIRP	71.2 dBW	54.3 dBW
Power (T_x)	19.4 dBW	-
Antenna Gain	53.9 dBi (2.5m)	-
Slant Range	40794.7	40794.7
Total Losses	-374.4 dbW	-379.5 dBW
G/T	6.7 dB/K	24.5 dB/K
Received C/No	89.6 dB.Hz	94.9 dB.Hz
Required C/No	88.7 dB.Hz	93.9 dB.Hz
Link Margin	1.0 dB	1.0 dB
Modulation	QPSK	QPSK
Required E_b/N_o	7.3 dB (BER:5.0E-4)	7.3 dB (BER 5E-4)
Bit $Rate_o$	78.7 dB.Hz (74.0 Mb)	83.1dBHz (204 Mb)

VII. SUMMARY OF LINK ANALYSIS

For option-1 in Table 6, the antenna size is less than 2.5 meter, Transmitting Power is 87.0 W, EIRP is 71.2 dBW and Noise power density is –203.9 dBW/Hz with 1 dB link margin..

For option-2 in Table 5, the antenna size is less than 3.3 meter, Transmitting Power is 50.0 W, EIRP is 71.2 dBW and Noise power density is –203.9 dBW/Hz with link margins of 1 dB and 3.5 dB for uplink and downlink respectively.

For option-3 in Table 4, the antenna size is less than 4.8 meter, Transmitting Power is 50.0 W, EIRP is 81.1 dBW and Noise power density is –-202.4 dBW/Hz with link margins of 1 dB and 7.5 dB for uplink and downlink respectively.

For option-4 in Table 3, the antenna size is less than 10.2 meter, Transmitting Power is 225.0 W, EIRP is 81.1 dBW and Noise power density is –-202.4 dBW/Hz with link margins of 1 dB for both uplink and downlink.

All options based on the ITU-R antenna pattern 29-25logθ.All options are based on analysis performed for QPSK modulation Scheme.All analysis was carried out under clear sky conditions. The link margins are subject the availability of the links at a certain a certain time and location.

VIII. FREQUENCY COORDINATION

For the proposed earth station and radio equipment, the technical regulation and operation methods specified in the ITU radio Regulations and other local and international laws will be observed. However, a radio station license is required to conduct the experiment.

IX. RECOMMENDATIONS

Based on the analysis given above, we recommend the following for the Earth Station design using WINDS system at Kuala Lumpur and Malacca, Malaysia:

The results given in Tables 5 & 6 demonstrate that the best available equipment for the options 1 & 2 is Super Data Rate-Very Small Aperture Terminal (SDR-VSAT) for APAA in both on board switching and bent pipe modes.

The results given in Tables 3 & 4 demonstrate that the best available equipment for the options 3 & 4 is Large Earth terminal (LET) for APAA in both on board switching and bent pipe modes.

X. CONCLUSION

WINDS experiment to be conducted by JAXA, Japan is a good opportunity for the countries under coverage to verify and validate Ka-band technology by conducting various experiments including but not limited to Tele-education, Tele-medicine, Propagation Modeling, Interference and compatibility analysis at ultra speed.

The proposed Earth Station Design is to conduct above-mentioned experiments at University Technical Malaysia, Malacca (UTeM) for acquiring technical know-how in Ka-band communications Technolgy.

XI. REFERENCES

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