A Study on the Application of ISDB-S to Future Digital Satellite Broadcasting in Mongolia

Mr. NORINPIL Erdenkekhuu of Mongolian National Radio and Television Authority conducted research on a digital satellite broadcasting system in Mongolia at STRL as a visiting researcher of the Asia Pacific Broadcasting Union (ABU) for one year, from September 2001. In this article, his one-year-term study is described.

1. Introduction
Atmospheric gaseous absorption effects and rain attenuation represent major propagation losses for satellite systems operating at frequencies above 10 GHz. To design an advanced broadcasting satellite system operating in the 17/21-GHz band allocated by ITU-R for future BSS (Broadcasting Satellite Service) systems, link budget analyzing programs based on worldwide long-term meteorological databases and ITU-R calculation models were developed. The MATLAB program language, which is commonly used for developing numerical computation programs, was used to do a worldwide and regional statistical analysis of propagation and meteorological parameters as well as a link analysis of the 17/21-GHz-band BSS system in capital cities of 106 ITU member countries.

The main research concerned application of ISDB-S to a future digital satellite broadcasting system servicing Mongolia. It comprised preliminary design of a 12-GHz-band broadcasting satellite, including the satellite antenna design, transponder design, bus design and system design characteristics such as frequency plan and service availability.

2. Worldwide and regional statistical analysis of propagation and meteorological parameters in BSS bands
The satellite downlink parameters correspondent with the small receiving terminal are the major constraining factors of the BSS system. To design a BSS system for operation in 12 GHz and higher bands, propagation parameters such as rain attenuation and atmospheric absorption must be considered. The block diagram given in Figure 1 shows worldwide, long-term meteorological databases and calculation models of ITU-R used for computing the following parameters with the MATLAB program:

Propagation parameters:
- Gaseous attenuation exceeded for 1% of the year [dB]
- Rain attenuation exceeded for 0.001% to 5% of the year [dB]

Meteorological parameters:
- Annual surface water vapor density exceeded for 1% of the year [g/m²]
- Annual mean surface temperature [°C]
- Rainfall rate exceeded for 0.01% of the year

Figure 1: Block diagram of the calculation program

Figure 2: World contour map of rain attenuation level exceeded for 0.1% of the year at 22 GHz
the year [mm/h]
- Height Above Sea Level (HASL) of receiving station [km]
- Rain height [km]

The MATLAB programs can be used up to 54 GHz for atmospheric gaseous attenuation and up to 55 GHz for rain attenuation exceeded for 0.001% to 5% of the year regardless of receiving location or satellite orbital position. The databases used in these programs were obtained from the ITU-R database and can be easily updated.

As an example, Figure 2 shows a world contour map of rain attenuation at 22 GHz exceeded for 0.1% of the year. Here, the satellite orbital position was assigned at the same longitude as the estimated location. In this map, contour area is limited by an elevation angle larger than or equal to zero, because a satellite located on a geosynchronous orbit cannot be seen from both polar areas.

3. Link analysis of 17/21 -GHz-band BSS system in capital cities of ITU member countries

For the purpose of transmitting studio-quality HDTV and other high data rate services, WARC-92 has allocated 21.4-22 GHz to ITU Region 1 (Europe and Africa) and Region 3 and 17.3-17.8 GHz to Region 2 (North and South America). The 17/21-GHz band has significant transmission losses due to rain attenuation and gaseous absorption compared with the 12-GHz band. This study gives a link analysis of the assumed transmission system and compares the rain attenuation and atmospheric absorption at 17/21 GHz with those at 12 GHz in capital cities of 106 ITU member countries. Hierarchical modulations and other

<table>
<thead>
<tr>
<th>Worst month Availability [%]</th>
<th>Countries</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCBPSK</td>
<td>QPSK 1/2</td>
<td>Region 1</td>
</tr>
<tr>
<td>Above 99.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99.9-99.6</td>
<td>Above 99.8</td>
<td>Belgium, Bosnia, Djibouti, Hungary, Italy, Senegal, South Africa, Zimbabwe</td>
</tr>
<tr>
<td>99.6-99.2</td>
<td>99.8-99.6</td>
<td>Uganda</td>
</tr>
</tbody>
</table>

Table 1: Classification of countries by worst month availability
parameters of the ISDB-S system, power flux density threshold and corresponding satellite BPR defined by ITU-R Resolution 525 and Section V of the ITU Radio Regulations (RR) Article 21, orbital positions allocated by RR Appendix 30 (AP30) for 12-GHz BSS system and related ITU-R Recommendations are used in the calculation of the link budget and propagation parameters.

The distribution of rain attenuation level exceeded for 0.1% of the year in the 12-GHz and the 17/21-GHz bands is shown in Figure 3, where number of cities within the attenuation ranges are shown in each Region. 0.1% of the average year corresponds to the value of 99.6% of the worst month service availability.

All countries included in the link analysis are classified, as presented in Table 1, by the worst month availability for TC8PSK and QPSK 1/2 modulations.

The countries with low rain attenuation (referred to as class A countries) can use the bands allocated for future advanced BSS service without any difficulty.

By applying the techniques of hierarchical modulation and variable satellite BPR, the class B countries can maintain a service availability of 99.6-99.9% (worst month) for individual reception without the need for a satellite transponder capable of generating extremely high power.

Class C and D ITU member countries experience very high rain attenuation levels, and in order for them to use 17/21-GHz band for future BSS and to meet the service availability requirement, additional mitigation technologies such as storage reception are needed.

4. Application of ISDB-S to future digital satellite broadcasting in Mongolia

Since 1991, Mongolian National Television programming has been broadcast throughout Mongolia using a 4-GHz-band analog satellite broadcasting system based on leased transponder capacity. Currently, one transponder with a 72-MHz bandwidth of INTELSAT’s 66°E satellite system is used for Mongolian satellite broadcasting. To overcome the disadvantages of 4-GHz-band analog satellite broadcasting, such as the large user terminal, limited number of programs and poor transmission quality, one of the 12-GHz-band digital transmission standards (European DVB-S, American DSS, DC-II and Japanese ISDB-S) can be introduced as the future broadcasting service in Mongolia.

4.1. 12-GHz-band DBS service based on leased transponder capacity in Mongolia

The advent of high-powered satellites allows for dishes as small as 45 cm in diameter and digital compression technology permits the broadcast of up to ten programs per transponder. At present, many local, national and international broadcasters have been leasing transponder capacity from satellite operators such as INTELSAT, ASIASAT and INTERSPUTNIK for satellite broadcasting, even though ITU-R has assigned a certain number of channels and orbital positions to each country for a 12-GHz-band DBS system.

Class B countries experience very high rain attenuation levels, and in order for them to use 17/21-GHz band for future BSS and to meet the service availability requirement, additional mitigation technologies such as storage reception are needed.

4.2. Preliminary design of Mongolian 12-GHz-band DBS satellite

ITU-R has allocated the orbital position of 74°E and ten RF channels for 12-GHz DBS service to Mongolia. The provisions and associated plan for broadcasting satellite in the frequency bands of 11.7-12.2 GHz in Region 3 and 11.7-12.5 GHz in Region 1 are given in RR AP30.

4.2.1. Satellite transmitting antenna design

Mongolian territory spans 2392 km from west to east and 1259 km from north to south; thus the cross-section of the satellite transmitting antenna beam should be elliptical. Accordingly,
a shaped beam offset parabolic-type antenna with three horn radiators was chosen. The antenna characteristics are given in Table 3. The downlink antenna gain contour is shown in Figure 4. The boresight gain, directed to a longitude of 102.2° and latitude of 46.6°, is 42.9 dBi, and the minimum gain at the edge of the service area is 36.9 dBi. The side lobe is (42.9-36.9) dBi.

4.2.2. DBS satellite design

In the transponder, ten TWTAs provide ring redundancy to transmit simultaneously a maximum of five 27-MHz-bandwidth channels selected by the ground command from the ten channels allocated to Mongolia. The beam center maximum ERP value is 58 dBW, which corresponds to 51-W TWT output power including compensation power for the 2 dB feeder loss. This ERP allows for DBS service with a 45-cm receive antenna within the area of Mongolia and meets the ERP limit given in RR AP30.

Table 3: Antenna Characteristics

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna type</td>
<td>Shaped beam offset parabolic</td>
</tr>
<tr>
<td>Frequency</td>
<td>12.3 GHz</td>
</tr>
<tr>
<td>Reflector size</td>
<td>2.3 m</td>
</tr>
<tr>
<td>Focal length</td>
<td>2.07 m</td>
</tr>
<tr>
<td>Polarization</td>
<td>Circular</td>
</tr>
<tr>
<td>Number of horn</td>
<td>3</td>
</tr>
<tr>
<td>Horn type</td>
<td>Circular step horn</td>
</tr>
<tr>
<td>Horn diameter</td>
<td>4.4 cm</td>
</tr>
<tr>
<td>Horn spacing</td>
<td>4.4 cm</td>
</tr>
<tr>
<td>Horn gain</td>
<td>15.4 dBi</td>
</tr>
</tbody>
</table>

Table 4: Satellite Payload Parameters

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload type</td>
<td>12 GHz band DBS</td>
</tr>
<tr>
<td>Frequency</td>
<td>12 GHz</td>
</tr>
<tr>
<td>Antenna Coverage</td>
<td>Domestic (Mongolia)</td>
</tr>
<tr>
<td>Number of channels</td>
<td>5 active channels</td>
</tr>
<tr>
<td>Channel bandwidth</td>
<td>27 MHz</td>
</tr>
<tr>
<td>Antenna type</td>
<td>Shaped beam Parabolic with 3 horn radiators</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>(42.9-36.9) dBi</td>
</tr>
<tr>
<td>Antenna mass</td>
<td>33 kg</td>
</tr>
<tr>
<td>HPA RF power</td>
<td>52 W</td>
</tr>
<tr>
<td>HPA efficiency</td>
<td>56 %</td>
</tr>
<tr>
<td>TWTA redundancy</td>
<td>Ring configuration (5 out of 10)</td>
</tr>
<tr>
<td>HPA DC power</td>
<td>92 W</td>
</tr>
<tr>
<td>Paylload mass</td>
<td>557 W</td>
</tr>
<tr>
<td>Transponder mass</td>
<td>64 kg</td>
</tr>
<tr>
<td>Payload mass</td>
<td>97 kg</td>
</tr>
</tbody>
</table>

Table 4's payload parameters such as mass and power requirements derived from fundamental performance requirements lead to the bus modelling. Table 5 shows the bus and satellite parameters of the assumed types of satellite (spin-stabilized HS376 and a 3-axis stabilized RCA3000). The Communication Satellite Sizing Model based on TelAstra Communication Satellite Databases is used as a reference in this preliminary design.

5. Conclusions

A preliminary design of 12-GHz-band broadcasting satellite system for Mongolia was presented on the basis of ISDB-S. The 12- and 21-GHz-band BSS systems in the future since rain attenuation is much lower than in countries with high rainfall levels. Also in the scope of this study, a link analysis of future 17/21 GHz band BSS system was conducted and propagation parameters were evaluated in capital cities of 106 ITU member countries. The results of this evaluation (including the programs for statistical analysis of propagation parameters) can be used to create databases for comparing experimental results and for designing satellite systems.

6. Acknowledgements

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