Toward Super-Hivision Broadcasting using 21-GHz Satellite Transmission Technology

~ Presentation at 2005 NHK STRL Open House ~

NHK Science and Technical Research Laboratories

1. Introduction

The next development coming in the wake of high-definition broadcasting is Super HiVision, which will have a resolution of over 4000 scan lines. In addition to extremely high resolution, Super HiVision will provide viewers with breathtaking realism and total immersion. To achieve Super-HiVision broadcastings, high-throughput transmission channels are needed. NHK Science and Technical Research Laboratories (STRL) are now studying on satellite broadcasting systems in the 21-GHz band as a new candidate to achieve Super-HiVision transmissions. This report provides an overview of our study progress.

2. Satellite broadcasting in the 21-GHz band for Super HiVision

A Super-HiVision signal requires a transmission speed of 48 gigabits per second (Gbps). Through digital compression technologies, this rate can be reduced to 200 to 400 megabits per second (Mbps).

The maximum transmission speed under current digital satellite broadcasting in the 12-GHz band is about 52 Mbps. In order to achieve Super-HiVision broadcastings, a new transmission system must be developed.

Through an agreement with the International Telecommunication Union (ITU), Japan is able to use a frequency band of 600 MHz (from 21.4 to 22.0 GHz) for satellite broadcastings. This band is expected to be used for Super-HiVision transmission.

Figure 1 shows the relationship among modulation method, transmission speed, and the number of channels for Super-HiVision satellite broadcasting in the 21-GHz band. It is assumed that conventional modulation methods are used. From the figure we can see that if it is possible to compress the transmission speed to 200 to 400 Mbps, two or three channels of Super-HiVision broadcasting will become available.

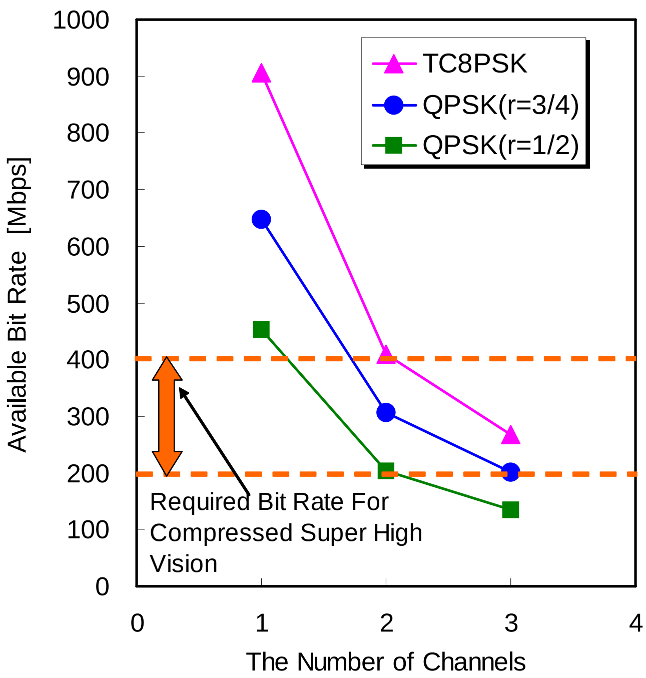

Figure 1: Relationship between the Number of Channels and Available Bit Rate

Table 1 shows the study items to develop Super-HiVision satellite broadcasting system. For transmitting a Super-HiVision

Table 1: Study Items for BSS in the 21-GHz band

Transmission technology	Study items
Channel coding	(1) Multiplexing (2) Modulation method(QPSK, 8PSK) (3) Error correction method (Reed-Solomon, convolution, trellis code, turbo code) (4) Interleave (5) Data storage type transmission scheme
Broadcast satellite	(1) Phased-array antenna (2) Transponder (Heat processing, modularization) (3) Low-cost amplifier (4) Generation of control information for bosted beam (5) Frequency sharing among satellites (6) Constraint unwanted emission (Protect radio astronomy) (7) Service availability (Same as current BS digital broadcasting) (8) Estimate rain attenuation from predicted rain fall data (9) Rain attenuation time-series model
Receiver	(1) Wide-band receiver (about 200 to 300 MHz) (2) Storage-type receiver (Built-in mass-storage device) (3) Low noise (NF less than 1.5 dB) (4) Super-HiVision display

signal in the21-GHz band using a satellite, it is needed to adjust the transmission power to compensate for rain attenuation and applying the high-capacity storage medium to the system should be also considered to achieve high service availability efficiently.

Rain attenuation in the 21-GHz band is about three times larger than in the 12-GHz band when compared in dB unit. This means heavy rain attenuation occurs much more frequently in the 21-GHz band. When heavy rain attenuation occurs, BS receivers can no longer receive satellite broadcastings. Most households today use a reception antenna of 45 cm diameter to receive BS digital broadcastings. If rain attenuation exceeds 5 dB in the 12-GHz band, reception of high-definition broadcastings is outaged. When we applied the method in ITU-R Recommendation P.618-8 and 1-minute-rain rate of 52.5 mm/h for annual time percentage of 0.01%. the outage time of HiVision broadcastings in the 12-GHz band can be estimated for about three hours in a year. For the 21-GHz band, the estimated outage time can be estimated 35 hours that is 10 times greater than the outage time in the 12-GHz band. From this result, it is considered that developing counter measures for rain attenuation is very important to achieve satellite broadcasting in the 21-GHz band.

3. Compensation technology for rain attenuation

3.1. Long-period interleave transmission using a mass-storage device

Heavy rain usually occurs sporadically over a short period. Taking this rain characteristic into account, the long-period interleave transmission method temporally diffuses program data by using long-period interleaver and transmits it. Transmitted data are stored at a mass-storage device in receivers. If data is later found to be missing or in error, a compensation algorithm can correct them effectively. However, long-period interleave transmission cannot be used for real time broadcastings because it is based on storing program data.

Figure 2 shows the improvement effect in service availability with using the long-period interleave transmission method. The improvement effect was evaluated based on actual rain attenuation data measured for three-year period in Tokyo. A tradeoff exists among aimed service availability, interleaving time, modulation method and error correction method. For example, by applying 1.6 interleave hours, service availability of 99.99% is achieved when using a combination of QPSK modulation (convolution code rate = 5/6), with Reed-Solomon code (200, 120). To apply this method more efficiently, analysis of rain attenuation time-series characteristics should be conducted in terms of the durations where rain attenuation that exceeds a threshold level and its occurrence probabilities.

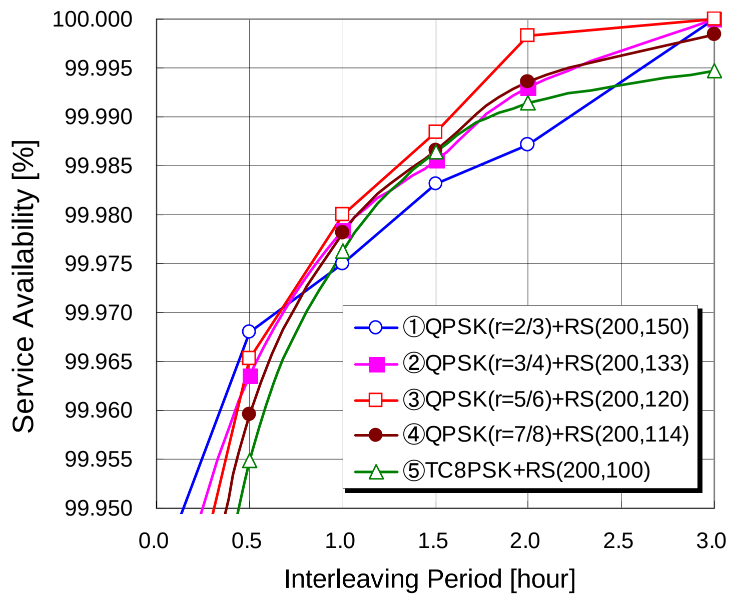

Figure 2: Relationship between Interleaving Time and Modulation and Error Correction Methods

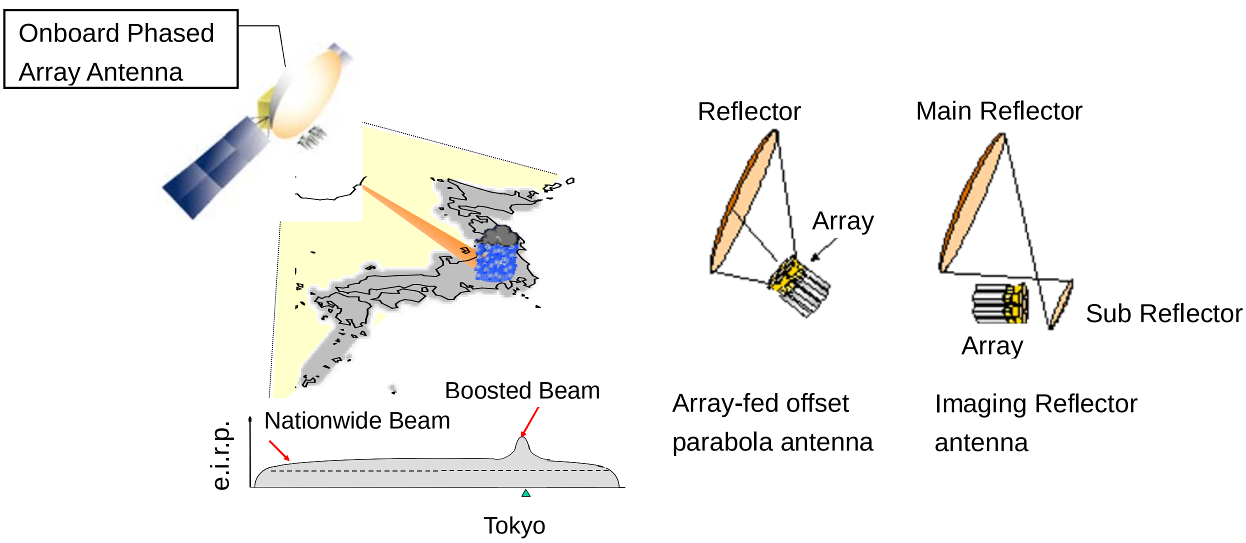

Figure 3: Broadcasting Satellite with Variable e.i.r.p system and Large Phased-Array-fed reflector Antenna

3.2. Variable e.i.r.p system

Conventional broadcasting satellites have been designed to cover the whole service area uniformly. It is uneconomical to boost transmitting power uniformly to compensate for rain attenuation because the scale of the satellite system (including transponders) would increase prohibitively. NHK STRL has been conducting research to develop technologies that effectively compensates for rain attenuation for satellite broadcastings in the 21-GHz band. The new broadcasting satellite system incorporates variable e.i.r.p system using a phased-array-fed reflector antenna to effectively boost signal strength in areas with heavy rain attenuation. Figure 3 shows an example of satellite system that employs variable e.i.r.p system using a large phased-array-fed reflector antenna. The antenna has a large reflector and multiple traveling wave tubes (TWT) on a feed array. The output phase and the amplitude of RF signal from each small TWT are adjusted and synthesized in space. While broadcasting service area is covered uniformly, emitted power to heavy rainy area can be boosted by the variable e.i.r.p.system.

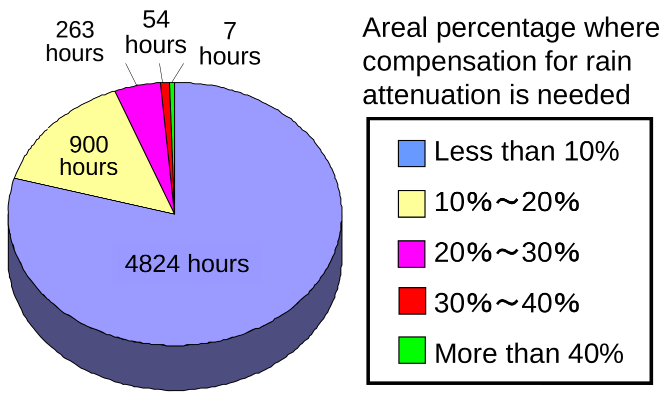

Figure 4: Areal Percentage of Rain Attenuation Compensation for Nationwide Service Area and Its Occurrence Time

Figure 4 shows the areal percentage for which compensation for rain attenuation is needed and its annual average occurrence time. This result is estimated by using AMeDAS 1-hour-rainfall data for 20-year period between 1979 and 1998. To conduct the survey, a Japan island is divided into 112 blocks of square. Compensated areas are determined by the rain fall data included in each block and the compensation areal percentage is calculated. It is assumed that the rain attenuation compensation is required when 1-hour rain fall data exceeds 3 mm. For 1-hour rainfall of 3mm, the average rain attenuation in the 21-GHz band is 3.5 dB. For a region with less than 1-hour rainfall of 3 mm, the area is assumed to be covered using the transmission power margin for clear sky. The figure shows that rain attenuation compensated area is less than 10% of whole service area for 80% of annual time. This means that boosting transmission power only for heavy rain attenuation areas can be an effective measure.

5. Conclusion

In this report, we introduced the broadcasting satellite system in the 21-GHz band by which Super HiVision-broadcastings can be expected. If we can apply compression technology to reduce the transmission speed down to 200 Mbps for Super-HiVision transmission, up to three channels will become available for Super-HiVision broadcastings. Rain attenuation is a big problem for satellite broadcasts in the 21-GHz band. As effective measures to overcome the rain attenuation, a long-period interleave transmission system and a broadcasting satellite system employing variable e.i.r.p system using a phased-array-fed reflector antenna are introduced. We are now going to study the method to estimate required transmission power of broadcasting satellite in the 21-GHz band by using predicted rain fall data for short period by Japan Meteorological agency. We are also planning to study rain attenuation time-series model, which is required to evaluate the long-period interleave transmission method.