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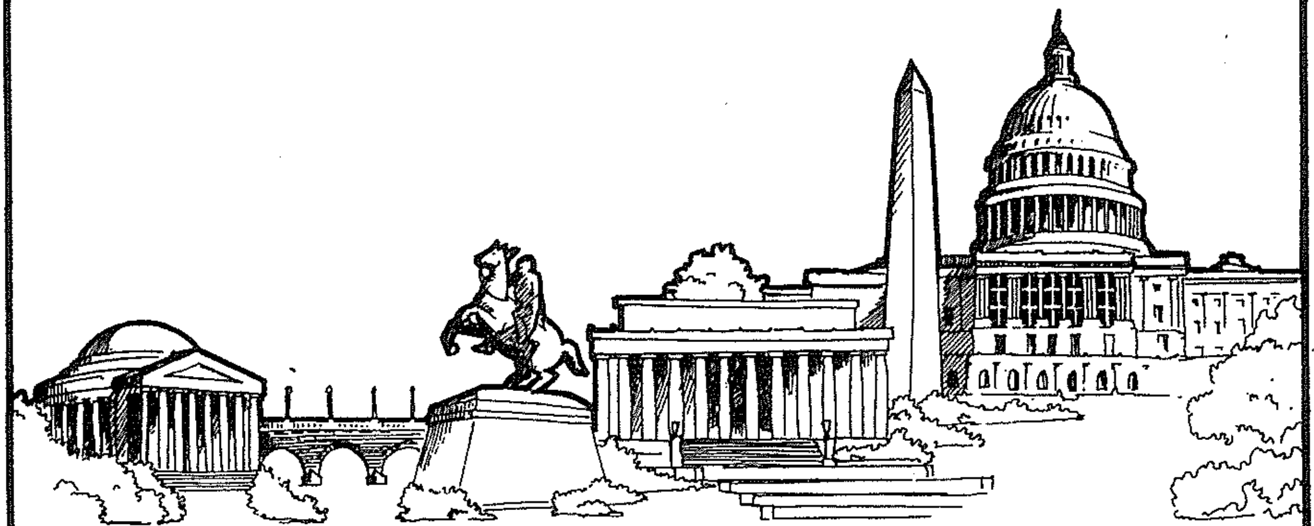

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EVALUATION OF SERVICE AREA IN THE SATELLITE BROADCASTING BY THE BSE

Minoru Yamamoto
Kashima Branch, Radio Research Laboratories, Ministry of Posts and Telecommunications
Hirai, Kashima-machi, Ibaraki 314, Japan
Shoji Sonoda
Nippon Hoso Kyokai (NHK: Japan Broadcating Corporation)
Jinnan, Shibuyaku, Tokyo 150, Japan

Abstract

We discuss received TV signal stability, a pointing error and radiation pattern of an on-board antenna, tracking errors of receiving antennas in earth terminals and rain attenuation in the BSE (Japanese Medium-scale Broadcasting Satellite for Experimental Purpose) experiments. The service area for the satellite broadcasting by the BSE is evaluated from these experimental results and statistical analyses.

The receiving antenna diameters to assure excellent or fine picture in the satellite broadcasting will be about 1 meter around the beam center of the on-board antenna, about 1.6 meters in the fringe area of the Japanese main lands and about 2.8 to 4.5 meters in the remote islands of Japan.

1. Introduction

The Japanese Medium-scale Broadcasting satellite Experimental Purpose (BSE) was launched on April 8, 1978. The BSE has been held within ±0.1 degrees in the geostationary orbit of 110 degree longitude. The pointing error is ussally less than 0.2 degrees (3σ). The BSE is a three axis stabilized spacecraft and has two direct frequency conversion transponders of 14/12 GHz band with 100 watt TWTs. A shaped beam antenna is boarded on the BSE to get adequate gain over the Japanese territory including outlying remote islands and to avoid spilling over neighbouring countries.

Picture quality of the standard FM-TV signal[1,2] in the BSE system is almost bounded only by a carrier to noise power ratio (CNR) at each earth terminal, since the transmission characteristics of the TV signal are so excellent. Therefore, it is sufficient only to pay attention to the CNRs of the received signals at various locations in Japan for evaluating the service area.

This paper mainly presents the down link radiation pattern and pointing error of the on-board antenna, the rain attenuation of the BSE down link and the tracking errors of receiving antennas in the earth terminals for the BSE TV signal. In addition to these, there have been some other items to be taken account of in evaluating the service area such as output power stability of on-board transponders, solar noise interference, and the pointing error and rain attenuation of the up link. But in the BSE experiments it has been shown that these items scarcely affect the evaluation of the service area.

2. Radiation pattern and pointing error

Fig.1 shows the down link radiation pattern of the on-board antenna which was measured in field before the launch of the BSE. In Fig.1 are also shown the location and antenna sizes of earth terminals distributed throughout Japan for the BSE experiments. Fig.2 shows the contour lines of the maximum variation of the received signal powers due to the pointing error of ±0.1 degrees of the on-board antenna. The contour lines were calculated from the radiation pattern shown in Fig.1.

The variation of the received signal power is dependent on a receiving location and shows different behavior according to the pointing error caused by the beam rotation or by the beam pointing of the on-board antenna. Most part of Japan is inside of the contour line of 1.5 dB. The variations are up to 2 or 2.5 dB at Yonaguni, Minamidaito, Wakkanai and Kashima where are located at the beam edge of the on-board antenna.

The diurnal variation of the received signal power has been 3 to 4 dB at Kashima, Main Transmit and Receive Station (MTRS). The magnitude of this variation is reasonable, considering the location of the MTRS in Fig.2.

3. Tracking loss in earth terminals

The tracking loss of a fixed receiving antenna on the earth becomes large according as the slant range between an earth terminal and a spacecraft becomes short. Fig.3 shows the calculated maximum tracking loss at two typical locations, Wakkanai and Yonaguni, when the on-orbit position of the BSE deviates ±0.1 degrees from the nominal position in the worst direction. The slant range is the longest at Wakkanai and the shortest at Yonai in the earth terminals.

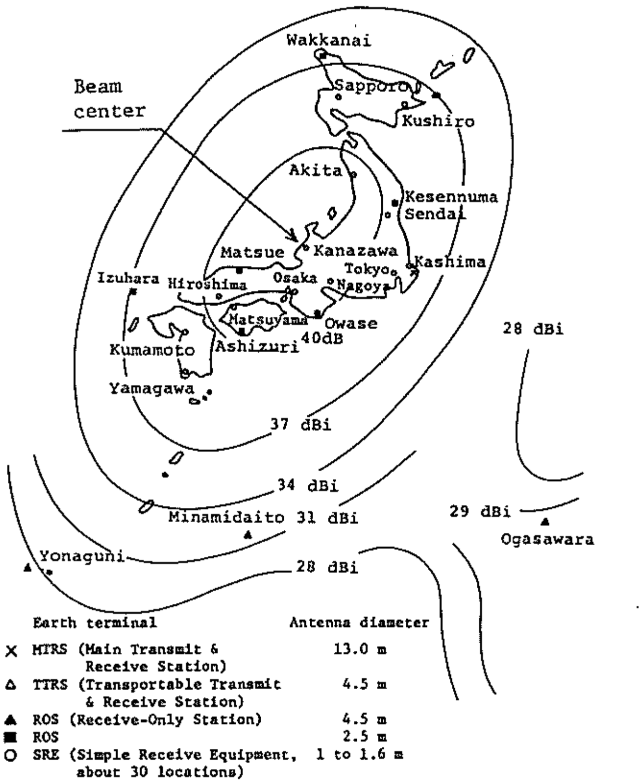

Fig.1 Radiation pattern of on-board antenna and earth terminal location for BSE experiments

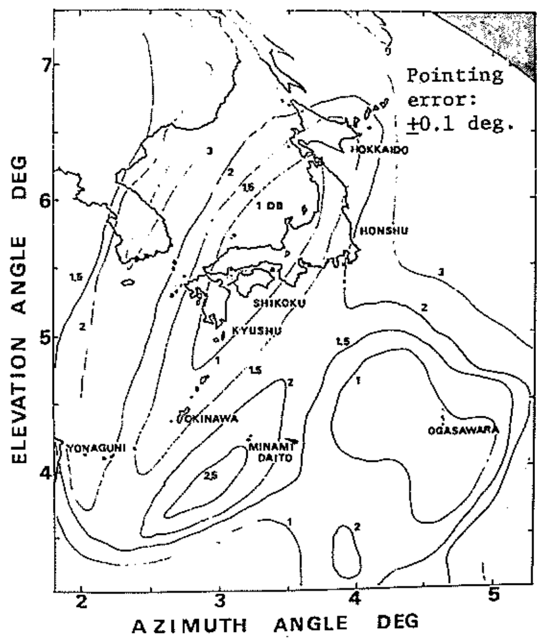

Fig.2 Maximum gain variation due to pointing error

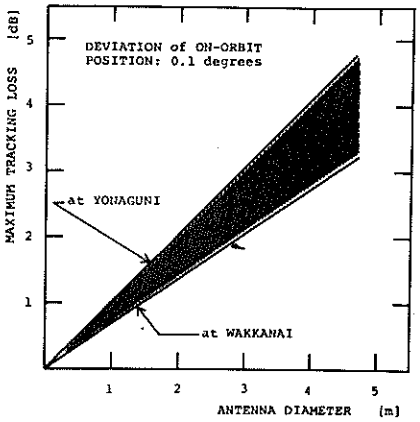

Fig.3 Tracking loss of fixed receiving antennas

The tracking loss can be almost neglected when a fixed receiving antenna is located in the Japanese main lands and its antenna diameter is less than 1.6 meters. The tracking loss is usually smaller than half the value shown in Fig.3.

4. Received TV signal stability

The received TV signal powers have been measured at various earth terminals located all over Japan. The transmitted and received signal powers of both the MTRS and the BSE have been always measured at the MTRS. Table 1 shows the mean values and the standard deviations (STD. DEV.s) of these powers in the standard FM-TV signal transmission. The mean values and standard deviations were calculated from the data measured at about the same time of days to avoid the effect of the diurnal variation described above.

The received powers are stable and their standard deviations are 0.5 to 0.9 dB. The received powers deviate about 1 dB at the BSE and about 2 dB at the MTRS from the calculated ones in the BSE link budget respectively. These disagreements would be due to the pointing and gain estimation errors of the on-board antenna, and the inaccuracy of the calibration curves for telemetry data. The variations of the transmitted powers have been scarcely observed.

Fig.4 shows the long term stability of the received powers measured for about two months at ten Receive-Only Stations (ROSs). The received signal powers were processed excluding the effect of rain attenuation. In the condition of the CNR more than 14 dB in the band width of 25 MHz, we can usually get excellent or fine picture in TASO scale in subjective assessment. The CNR of 14 dB corresponds to about 46 dB of the weighted signal to noise power ratio of the received picture in the BSE standard TV signal.

The variations of the received signal powers are up to 5 dB in Ogasawara, Minamidaito and Yonaguni. These stations are located at the beam edge of the on-board

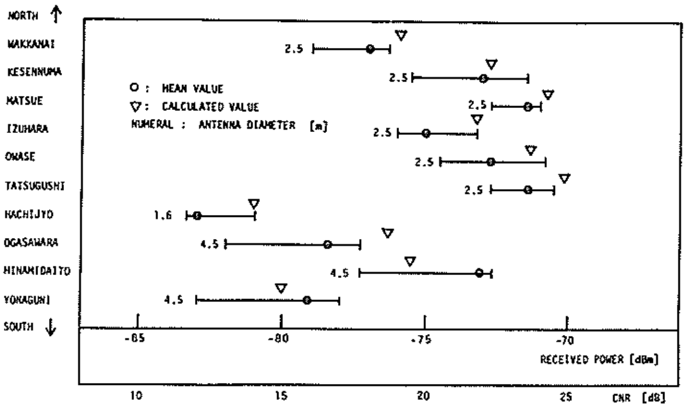

Fig.4 Long term stability of received powers at ROSs

Table 1 Transmitted and received powers at BSE and MTRS

CHANNEL	MEASUREMENT INTERVAL		NUMBER OF DATA	EIRP AT MTRS [dBm]	BSE SPACECRAFT				RX POWER AT MTRS [dBm]	
					RX POWER [dBm]		TX POWER [dBm]			
						STD.DEV.		STD.DEV.		STD.DEV.
A	AUG.14	OCT.20'78	25	112.1	-57.9	0.7	50.4	0.03	-60.2	0.5
	OCT.21'78	JAN.22'79	20		-57.8	0.5	50.4	0.04	-60.1	0.6
	JAN.23	MAY 24'79	41		-57.2	0.7	50.3	0.07	-60.1	0.6
B	AUG.14	OCT.20'78	40	112.2	-57.6	0.8	50.1	0.10	-60.1	0.7
	OCT.21'78	JAN.22'79	31		-57.5	0.7	50.1	0.14	-59.9	0.6
	JAN.23	MAY 24'79	46		-57.9	0.7	49.9	0.14	-60.1	0.9
CALCULATED					-56.7				-58.0	

antenna. Therefore, the pointing loss of the received signal is comparatively large. In addition to the fact, the variations include the loss of 2 dB which is inevitablely caused by the simple tracking system in those stations. The receiving antennas of the other seven stations are fixed to the nominal direction of the BSE. The variations in Kesennuma, Owase and Izuhara are larger than those in other stations in the main lands. The variations are very small in Matsue and Tatsugushi, which are located around the beam center of the on-board antenna. These phenomena might be due to the regional characteristics of the pointing error of the on-board antenna.

The received powers were measured at about the same time at 39 earth terminals located all over Japan. Fig.5 shows the distribution of the deviation of the received powers from the calculated ones. The deviation is within 1 dB for 75 % and 2 dB for 87 % of the number of the locations respectively.

It has been confirmed that the rotation of the radiation pattern of the on-board antenna corresponds to the tendency of the variations of the received signal powers at the MTRS and the ROSs. The rotation of the radiation pattern has been estimated from the telemetry data of the attitude control subsystem in the BSE, or the radiation pattern and the variations of the received signal powers at the ROSs. It can be judged from the results of the investigations described so far that the radiation pattern measured in field before the launch of the BSE is approximately realized by the on-board antenna.

5. Rain attenuation in down link

Various kinds of analyses[3] for propagation data at each earth terminal are continued to study statistical and regional properties of rain attenuation for getting actually required link margin in satellite broadcastings. The measurement system for propagation data contains a rain radar, radiometers, rain-guages and other meteorological instruments.

Fig.6 shows the cumulative distribution curves of the rain attenuation of the beacon signal of the BSE and ETS-II satellite at Kashima station, which is located about 100 kilometer east of Tokyo. Distribution curves of rain rate in one year are also shown in Fig.6. The rain attenuation is about 1, 2 and 7 dB for 1, 0.1 and 0.01 % of time (one year) respectively. These values agree well with those of the rain attenuation[4] measured by solar noise in 12 GHz band in Tokyo during 1967 to 1969. The rain attenuation measured by solar noise was used to evaluate link margin at the beginning of the BSE program.

As shown in Fig.6, the rain attenuation in the worst month is about 2, 5 and 9 dB for 1, 0.1 and 0.01 % of the time respectively.

Rain attenuation was estimated from the statistical data of rain rate for the past decade in all over Japan[5]. In the estimation process, a cumulative distribution of rain rate was expressed by a log-normal distribution function and the rain attenuation was calculated by a spacial correlation function[6]. Fig. 7 shows the regional properties of the estimated rain attenuation in the down link of the BSE for 1 % of the time in the worst month in Japan. The estimated rain attenuation is 1 to 2 dB in most part of Japanese main lands. The estimated rain attenuation at Kashima is about 2 dB and approximately coincides with the value measured in Augst 1977 shown in Fig.6.

The receiving antenna diameters, which assure the CNR more than 14 dB for 99 % of the time in the worst month, were calculated from the radiation pattern of the on-board antenna and the estimated rain attenuation as shown in Fig.8. In the calculation of the diameters, the effects of the pointing and the tracking errors described above sections are not taken account of. The contour lines of the calculated diameters reflect the radiation pattern of the on-board antenna, since the rain attenuation is not so large.

6. Conclusion and remarks

The summarized results of the experiments and the statistical analyses are shown in Table 2. The required antenna diameters shown in table 2 will assure the CNR more than 14 dB for 99 % of the time in the worst month in the satellite broadcasting by the BSE. The antenna diameters were estimated assuming that the rain attenuation would be uniformly 1.5 dB in Japan for 99 % of the time in the worst month. These diameters are approximately equal to the values estimated in the initial link budget in the BSE program.

The subjective assessment of received picture quality is continued by using color-bar and specially prepared VTR signals at various locations and has been almost excellent or fine in TASO scale.

We will continue to study the regional properties of rain and snow attenuation as well as other experiments in the BSE program to evaluate the service area in detail. Wet snow, especially wet snow lying on a receiving antenna attenuates severely a received signal. We need to study its mechanism and statistical characteristics and to develop the methods of improvement, because we have heavy snow in some part of the Japanese main lands.

Table 2 Summarized results of service area evaluation

RECEIVING AREA	GAIN OF THE ON-BOARD ANTENNA [dB]	MAXIMUM POINTING LOSS OF THE ON-BOARD ANTENNA [dB]	TRACKING LOSS OF RECEIVING ANTENNA	REQUIRED DIAMETER OF RECEIVING ANTENNA [m]
AROUND THE BEAM CENTER OF THE ON-BOARD ANTENNA	40−41	<1	SMALL	0.75−1
FRINGE AREA OF THE JAPANESE MAIN LANDS	37−39	1.5−2	SMALL	1.6
THE REMOTE ISLANDS OF JAPAN	28−31	2−2.5	LARGE	2.8−4.5

7. Acknowledgement

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8. References

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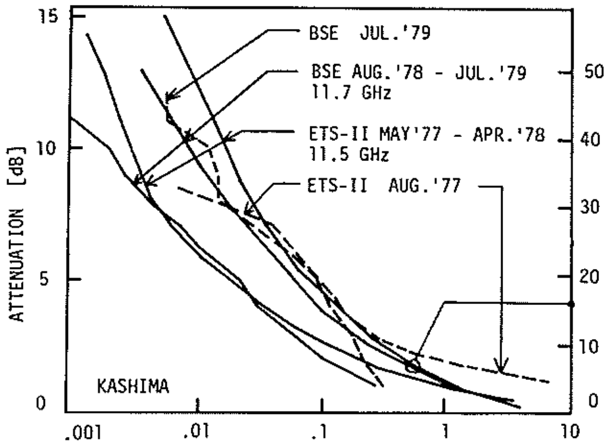

Fig.6 Measured rain attenuation at Kashima

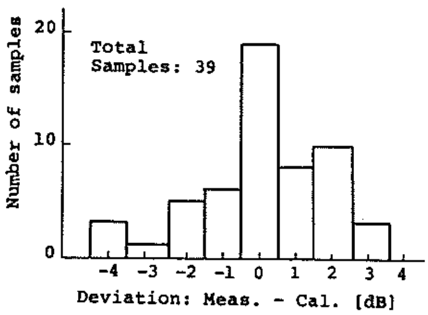

Fig.5 Distribution of received powers in 39 locations

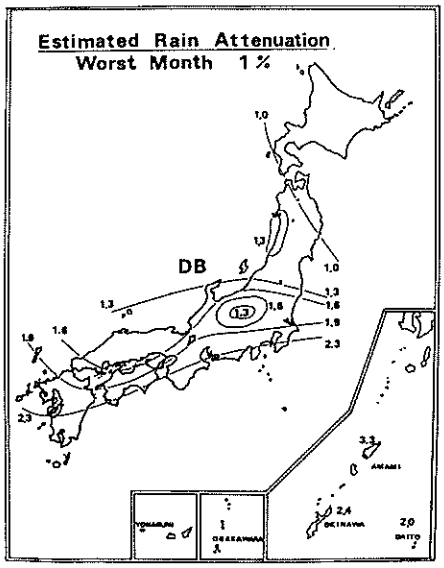

Fig.7 Estimated rain attenuation for 1 % of time in the worst month

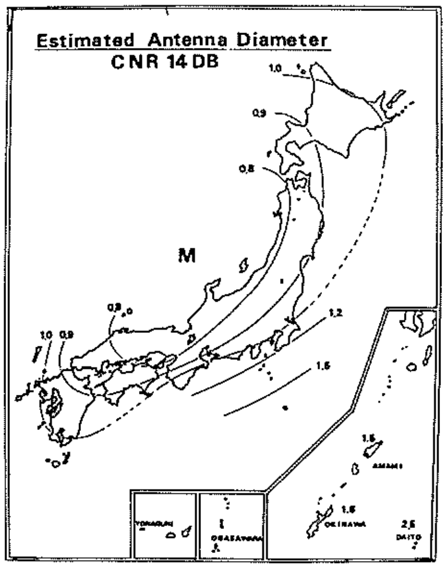

Fig. 8 Estimated receiving antenna diameters to assure CNR 14 dB