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PROPAGATION MEASUREMENTS AND TV-RECEPTION TESTS WITH THE JAPANESE BROADCASTING SATELLITE FOR EXPERIMENTAL PURPOSES

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Summary

In July 1978, stationary experiments were commenced with the Japanese Medium-Scale Broadcasting Stellite for Experimental Purposes (BSE). In this BSE project, frequencies of 14/12 GHz are applied to the up and down links, respectively, and experiments have been carried out from the points of propagation and receiving. The analysis of the propagation measurements revealed statistics of rain attenuation in various parts of Japan. By the TV-reception tests, it has been confirmed that received power was generally coincided with the predicted one and received picture was excellent at each receiving location which was distributed all over Japan.

I. Introduction

The Japanese Medium-Scale Broadcasting Satellite for Experimental Purposes (BSE) was launched on the 8th April 1978 from the Eastern Test Range in the U.S.A., and was put into the stationary orbit at the longitude of 110 degrees east. After several check-outs of the transponders, stationary experiments were commenced in July 1978. The BSE project was planned for investigation of solutions to various kinds of difficulties in TV-reception such as the one in isolated islands with no microwave network service and the one in highly built-up cities with shielding and scattering of radio waves by buildings, and realization of educational broadcasting and others.

The frequency band of 12 GHz allocated to satellite broadcasting has been applied to the down-link in this experiment, together with 14 GHz to the up-link. Since these frequencies are more easily affected by rainfall and snow than 4/6 GHz of the C-band, it is necessary to investigate propagation characteristics in various kinds of climate in Japan, in order to know how much percentage of the time is guaranteed for the satellite broadcasting.

For about ten years, many measurements of slant path attenuations were conducted around the frequencies mentioned above using radiometers in Japan, (1)-(4) and also with the radiometric and satellite techniques in other countries. (5) They become the basis of the BSE propagation experiment.

In this paper, several propagation charactristics obtained at various locations in Japan, concerning 14 and/or 12 GHz along the satellite-to-earth path for periods up to about one year are introduced, and some results of TV-reception in various places are also introduced.

II. Measurement system

In Figure 1 are shown locations of the participating stations which are plotted on the map of Japan, with contours of equi-level of the satellite transmitting antenna gain. Main Transmit Receive Station (MTRS) is located at Kashima which usually transmits TV and command signals for experimental purposes. Tracking and control of the BSE are performed by National Space Development Agency of Japan (NASDA) through the S-band signal. One of two Transportable Transmit Receive Station (TTRS) is usually located at Osaka and the other mounted on a car moves place to place all over Japan. Receive-Only Stations (ROS) and Simple Receive Equipments (SRE) are also incorporated into the experiment.

The locations of the stations concerned with the propagation measurements are listed with their pertinent parameters in Table 1. At the MTRS, the K-band beacon level (11.7 GHz) is received for measuring rain attenuation and depolarization. The other stations usually receive the TV signal which is transmitted from the MTRS or TTRSs. For TV-reception tests additional SREs of about thirty are further incorporated.

A schedule of TV-transmission is as follows; usually two channels are transmitted from Monday noon to Friday evening, one of which is used for propagation purposes during day and night-time

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and the other is normally for day-time TV-transmission experiment.

III. Data acquisition and processing

The propagation data obtained at each location are collected and recorded at each experimental center of the Radio Research Laboratories (RRL) and Nippon Hoso Kyokai (NHK) participating the experiment.

The measured data at the MTRS are processed and edited by an on-line computer. In parallel with the measurement of radio signal from the satellite, several kinds of observations have been conducted in the MTRS, using a network of rain-guages, a rain radar of the C-band and others. The data obtained at local observatories of the RRL are recorded on cassette magnetic tapes, which are mailed to the MTRS to be edited on conventional magnetic tapes (MT) together with the other data.

Concerning with NHK, the transmission of data measured and temporarily memoried at the TTRS and ROSs is performed daily through telephone lines or via. the BSE in-band talk channel, (6) and finally the data are edited on MTs.

The items of the data pertinent to the propagation measurement are listed in Table 1. By the TV-reception tests are obtained data as follows; 1) received power, 2) SN ratios of picture and sound, 3) quality of received picture, and 4) dependence of these values on the directivity of the BSE transmitting antenna at each location.

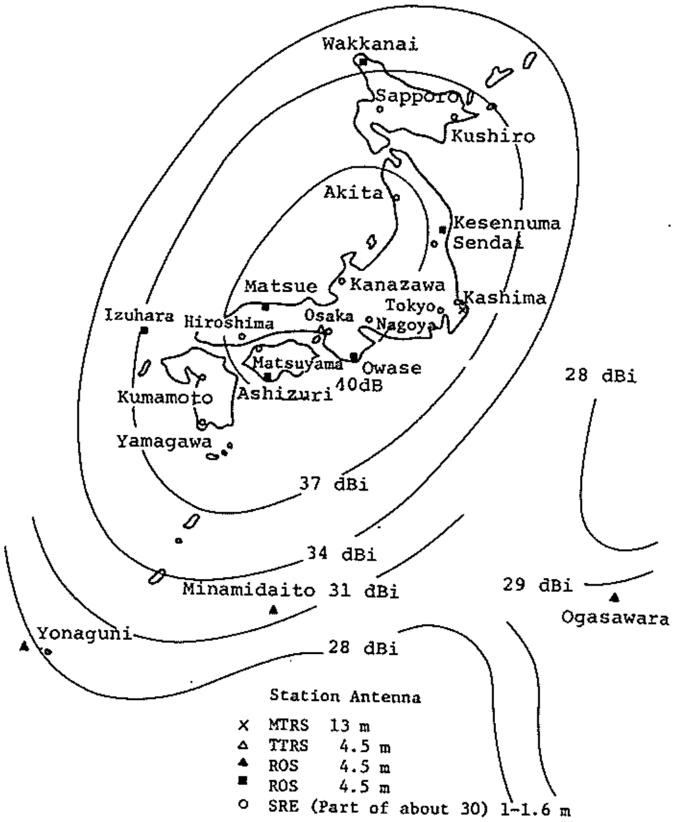

Figure 1 The BSE antenna radiation pattern and ground station location

Table 1 Participating stations and parameters for propagation measurements

Location	Station (antenna)	Climate	Elevation angle (°)	Data items	Measuring interval
Kashima	MTRS (13m) RDR		37.7	Level of Ku band beacon Level of TV signal System noise temperature Axial ratio Polarization angle	1 sec
				Satellite telemetry data	1 or 16 sec
				Rainfall and other meteorological data	1 min
Kokubunji	SRE (1m)		38.4	Level of TV signal Level of pilot signal	1 min
Wakkanai	ROS (2.5m)	much snow	29.1	Level of TV signal Rainfall, temperature	
Yamagawa	SRE (1.6m)	much rain	47.3		
Akita	SRE (1m)	much snow	34.6		
Okinawa		Strong winds	53.6		
Ogasawara	ROS (4.5m)	Strong winds	42.5	Wind, temperature	1 hr
Minamidaito		much rain &	51.7		
Yonaguni		Strong winds	57.9		
Kesennuma	ROS (2.5m)		34.4	Level of TV signal Rainfall	
Owase		much rain	41.5		1 min
Matsue		Snow	42.0		10 min (and 1 min for Owase)
Ashizuri		much rain	44.6		
Izuhara			45.2		
Osaka	TTRS (4.5m)		41.4		
Tokyo	SRE PLR (2.4m) RMR		38.2	Level of pilot signal	1 min
				Temperature Rainfall	1 and 10 min

MTRS : Main Transmit Receive Station
TTRS : Transportable Transmit Receive Station
ROS : Receive-Only Station
SRE : Simple Receive Equipment
RDR : Rain Radar
PLR : Pilot Receiver
RMR : Radiometer

One of the most important points of processing is how accurately and efficiently to extract additional attenuation due to rainfall from given data. The received power can be fluctuated with influence of such factors as attitude and orbital position of the satellite and pointing error of a receiving antenna.

Examples of received power are presented as the upper curves in Figure 2. The results include considerable amount of fluctuation, which ascribe to the non-propagation effects mentioned above.

However the examples shown are rather extreme cases, efficient elimination of the undesired fluctuation is essential to perform the propagation measurements. The adopted procedure for this purpose is shown in Figure 3. The procedure is based on the findings that the fluctuation is consisted of 1) component with regular diurnal variation peculiar to each location, 2) component showing correlation between the data obtained simultaneously at each location around 02:00 and 14:00 J.S.T. (Japan Standard Time), which correspond to noon and midnight at the satellite orbit, and 3) irregular component of fluctuation. As the variation due to rain attenuation hardly shows such regular diurnal variation nor has correlation with data at a distant location, the remaining irregular component must be caused by attenuation due to rainfall.

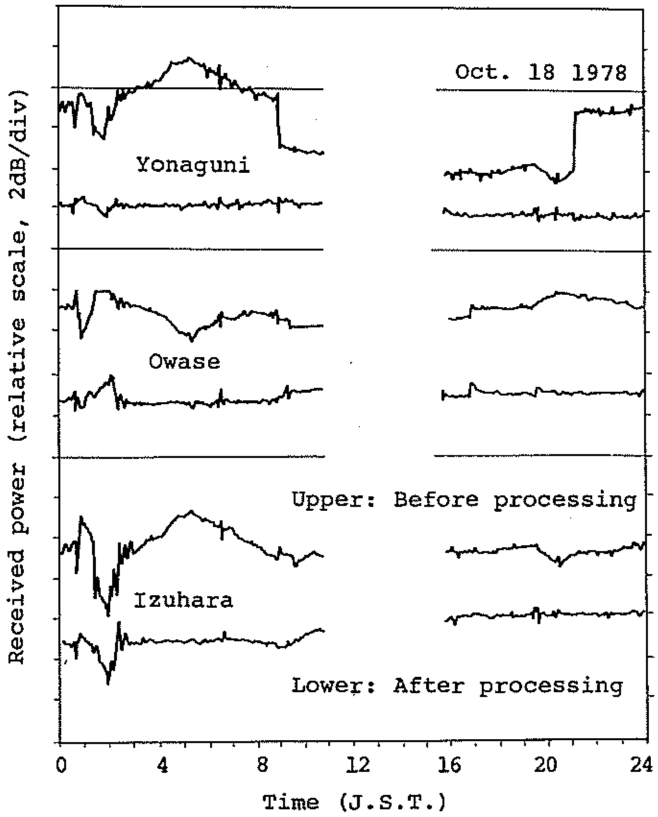

Figure 2 Examples of data before and after processing

Examples of the corrected data with this procedure are shown as the lower curves in Figure 2. From the comparison between the upper and lower curves it is understood that the unwanted fluctuation is farely well eliminated, although the component with correlation is not enough corrected with a method under improvement.

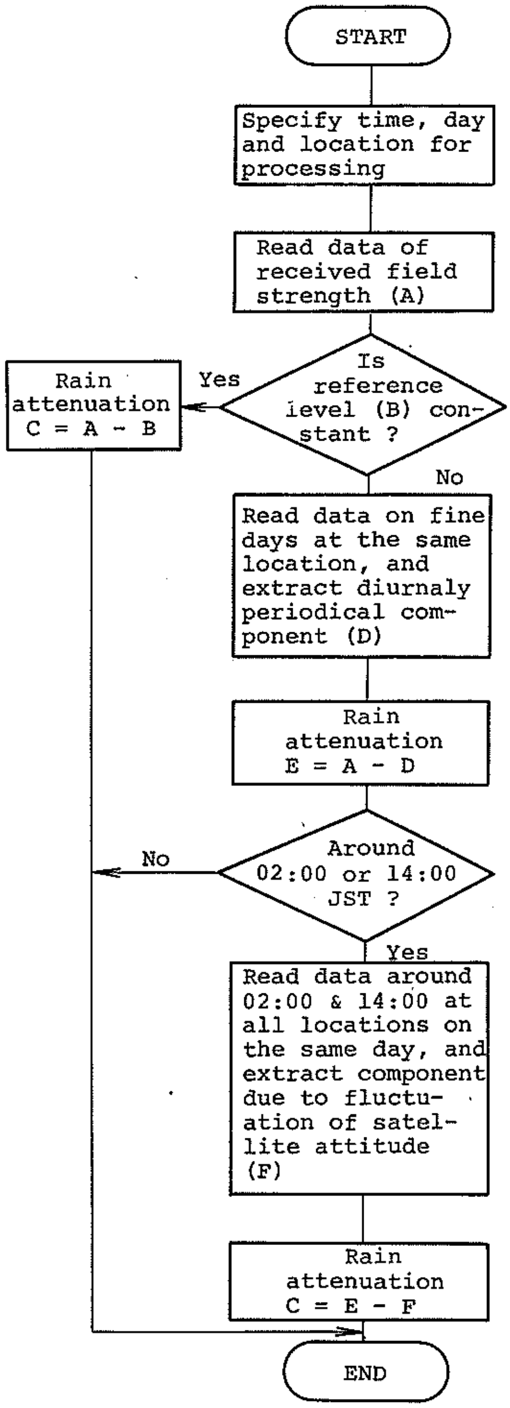

Figure 3 Procedure for extraction of rain attenuation from given data

IV. Results

1. Attenuation due to rainfall

1.1 Examples of attenuation events

In Figure 4 are shown, from above, excess noise temperature, beacon level, axial ratio of polarization and rainfall. Around 09:00 J.S.T. attenuation reached 11 dB and the maximum rainfall rate was 103 mm/h. In the same figure variations of excess noise due to rainfall and attenuation show a good correlation each other, and a scatter diagram of them is given in Figure 5, which shows a good regression except for smaller attenuations.

The radiometric measurement, especially the passive one can tend to under-estimate the true attenuation for higher frequencies. Parallel measurements have been carried out with passive radiometric and satellite techniques in Tokyo, using a 11.8 GHz radiometer and the BSE pilot signal (12.126 GHz). Comparison between them has given farely good coincidence. A typical example of the comparison in events of two rainy days is shown in Figure 6.

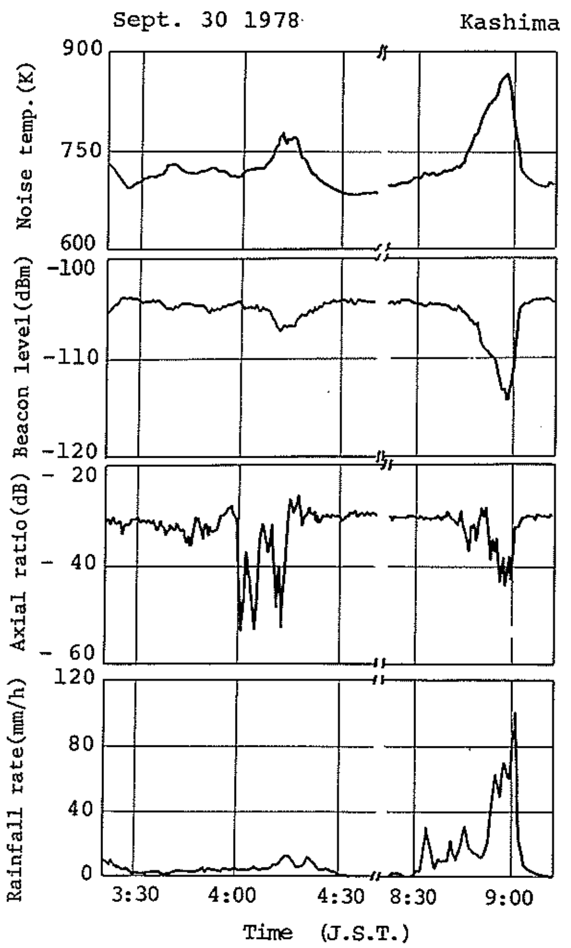

Figure 4 Typical examples of rain attenuation events at Kashima

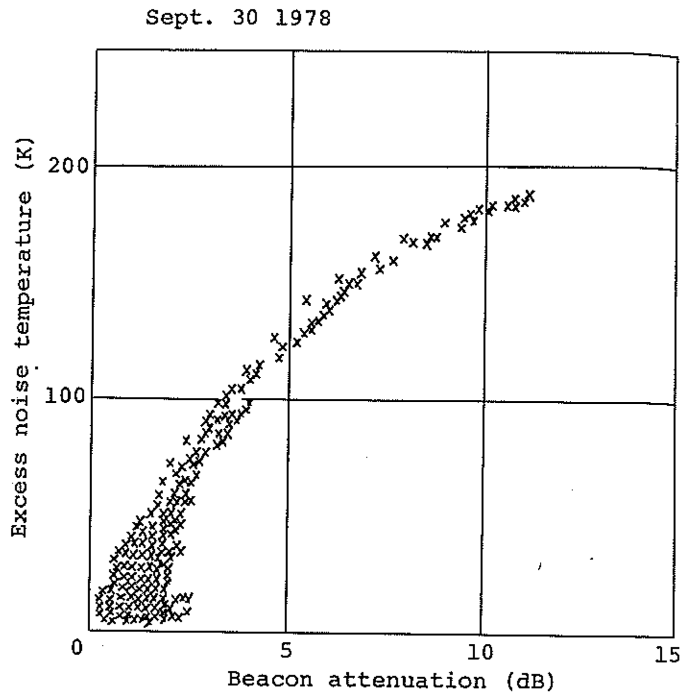

Figure 5 Relation between measured excess noise and rain attenuation at Kashima

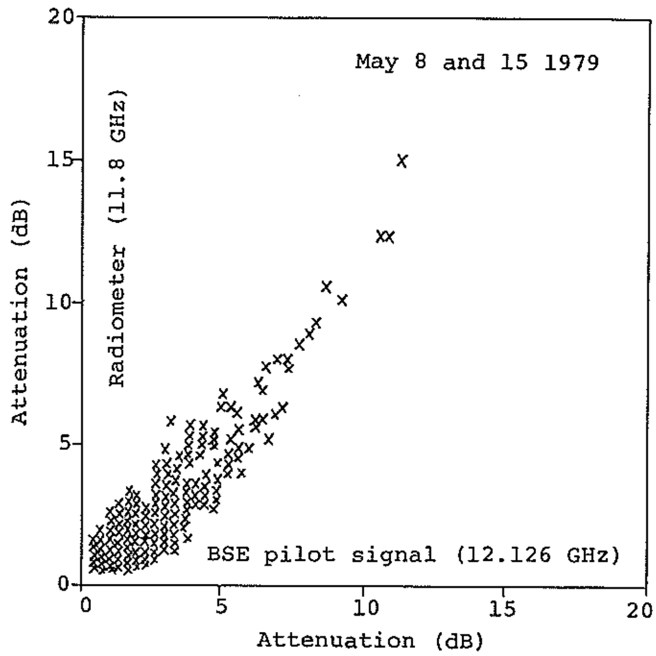

Figure 6 Relation between measured attenuations with radiometric and satellite techniques

Next in Figure 7 is shown an example of comparison between rain attenuations of the up- and down-links on a rainy day at Kashima. The plotted data are scattered a little for smaller attenuations. The ratio of attenuation of the up- to the down-link in decibel is about 1.4 which is almost equal to the theoretical value. As this relation was kept for other various rain events, it is possible to convert the statistics of the down-link to the ones for the up-link.

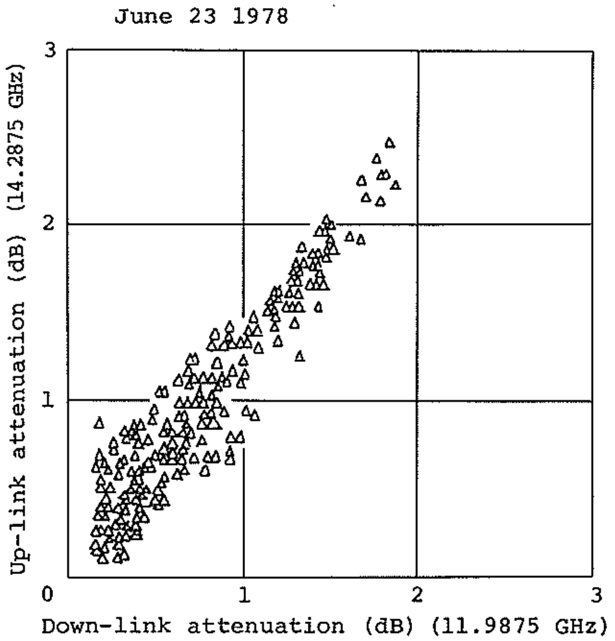

Figure 7 Relation between measured attenuations of up and down links at Kashima

1.2 Attenuation statistics

Figure 8 shows cumulative distribution curves of attenuation of the BSE beacon signal (11.7 GHz), as well as the ones from the propagation experiment with the Engineering Test Satellite type II (ETS-II), which was performed during May 1977 to April 1978 using 11.5 GHz. As the frequency in the ETS-II is close to the one in the BSE, the statistical curves of the ETS-II can be applicable also for the down-link of the BSE.

Figure 9 presents cumulative distributions of rainfall rate at the main station. Correlation between the curves in Figure 8 and those in this figure is not good. Because the distribution of rainfall covers 100% of the time and that of rain attenuation covers only about 70% due to various troubles of the system.

Since in a satellite broadcasting system rain attenuation on an up-link can be usually compensated by the margin of transmitting power, it is more important to know statistics of the rain attenuation on a down-link such as shown in Figure 8.

The statistics of the rain attenuation must be obtained at various places of Japan which are located in different kinds of climatic conditions, so that receiving system parameters such as size and type of an equipped antenna can be determined to be required for satisfactory satellite broadcasting service which is guaranteed for a specific percentage of the time to a specified place.

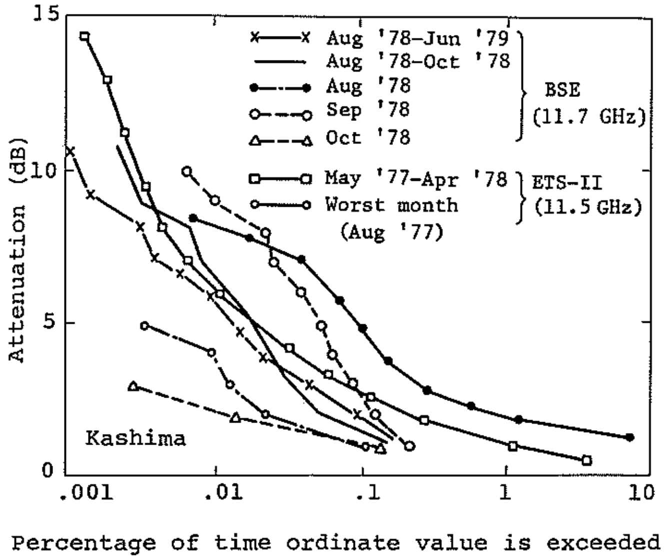

Figure 8 Measurements of rain attenuation at Kashima

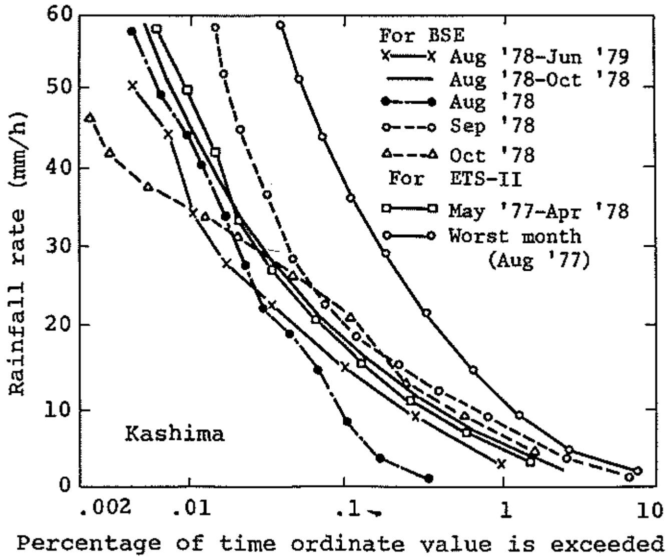

Figure 9 Measurements of rainfall rate at Kashima

Cumulative distributions of rain attenuation and rainfall rate were derived from the data obtained at the ROSs and the TTRS during August to December, 1978. In Figure 10 are shown the distributions for two typical locations, Owase and Kesennuma where were with the maximum and minimum rainfalls, respectively, during the observation. In Table 2 rain attenuation and rainfall rate are given for 1 and 0.1% of the time at each location, which were read from the above-mentioned distributions, together with the corresponding observed time. The observation of attenuation has been limited due to cease of the transmission on Saturday and Sunday, besides at nighttime in the beginning of the measurements. The rainfall rates in Table 2 are different from the ones to be read in Figure 10, because the rainfall data in the figure are employed during the observation of attenuation only.

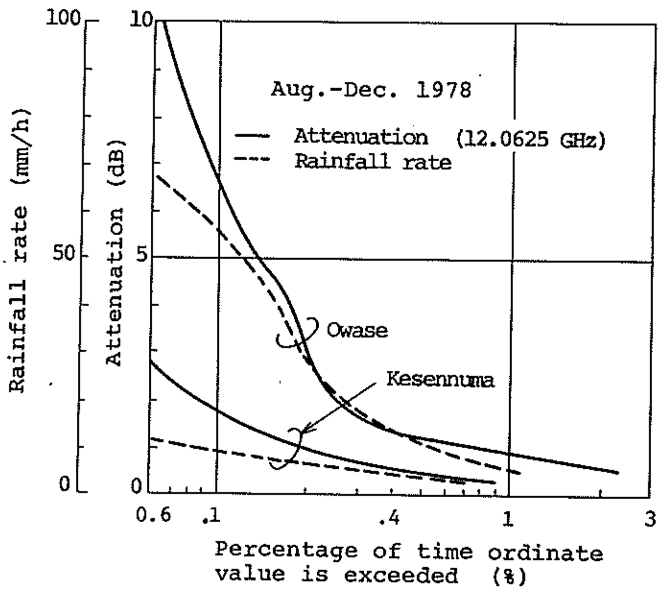

Figure 10 Measurements of rainfall rate and attenuation at rainy and dry locations

In Figure 11 are plotted points at which attenuation and rainfall rate occurred for the same percentage of the time. From the figure, effective path length is about 5 km, which is almost coincided with the one in CCIR Report (5) and the result by the ETS-II.(7) Effective path lengths were also derived from the measurements at the ROSs, of which the values for typical locations are given in Table 3. In comparison with the above-mentioned value at Kashima and the ones quoted in the same table from the CCIR Report, the ones in the table are considerably shorter for severe rainfall rates. Although this may be ascribe to difference of meteorological conditions between the measuring locations, more data are needed to draw a conclusion.

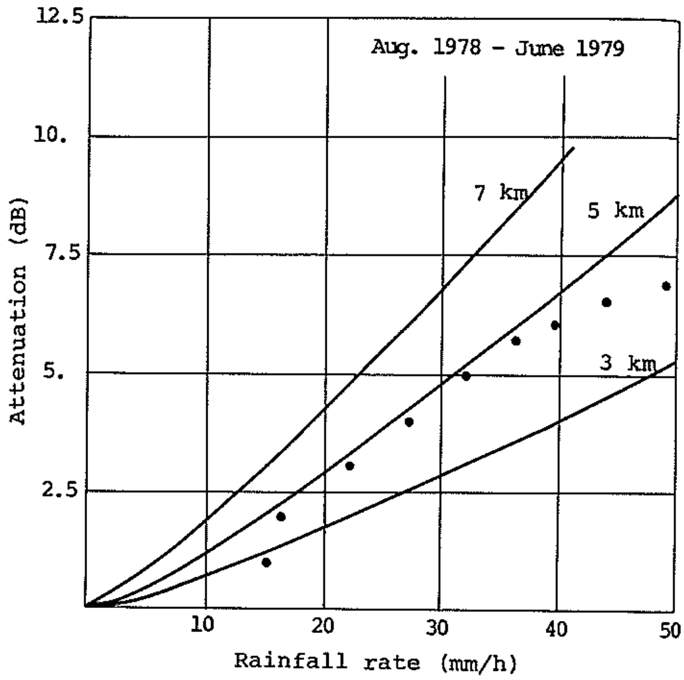

Figure 11 Effective path length obtained at Kashima

Table 2 Measurements of attenuation and rainfall rate at ROSs and TTRS (12.0625 GHz, August to December 1978)

Item / Location	Attenuation exceeded for given % (db)		Rainfall rate for given % (mm/h)		Observation Time (1000 min)	
	1	0.1	1	0.1	Attenuation	Rainfall
Ogasawara	/1)	1.1	3	19	29	82
Minamidatio	0.8	2.3	6	15	37	98
Yonaguni	2.3	5.5	6	39	34	59 2)
Kesennuma	0.3	1.7	4	12	38	160
Owase	0.8	6.5	13	52	41	164
Matsue	1.2	3.0	7	15	40	162
Ashizuri	1.2	3.3	6	28	39	162
Izuhara	/1)	/1)	7	20	32	161
Osaka	1.6	3.9	5	12	34	165

Note 1) No significant data due to trouble of equipment.

2) Observation time becomes shorter due to failure of rainguage.

Table 3 Effective path length obtained at rainy and dry locations

Location	Effective path length for given rainfall rate (km)		
	10 mm/h	25 mm/h	50 mm/h
Owase : rainy	4.3 (5.3)	3.2 (4.7)	2.6 (3.8)
Ashizuri : rainy	5.0 (5.1)	2.9 (4.5)	2.6 (3.7)
Kesennuma : dry	6.8 (6.3)	/	/

Note The values in ( ) are derived from Fig. 2 of CCIR Rep. 564-1 (Tokyo area)

2. TV-reception tests

2.1 Received power and its stability

It has been confirmed by the measurements carried out simultaneously at 39 locations all over Japan that received power was generally coincided with the corresponding predicted one. Deviation of the received power from the prediction was within 1 dB for 75% of the measurements, as shown in Figure 12.

Comparatively long term variations of received power were measured at the ROSs. At the beam edge of the satellite transmitting antenna, where are situated the ROSs on the isolated islands, the variation showed a maximum and reached up to about 5 dB, which included pointing error of 2 dB inevitable to the simple tracking antenna equiped there.

Quality of received picture has been assessed subjectively to have been excellent at each location, using color-bar and specially prepared VTR signals.

From the TV-reception tests, an antenna size has been derived which was required to obtain weighted S/N of picture of more than 45 dB for 99% of the time at each location. The required diameter is about 1 m around the center of the beam of the transmitting antenna, about 1.6 m for the fringe area of the mainland and 2.8 to 4.5 m for the isolated islands. These meet approximately the initial design specification.

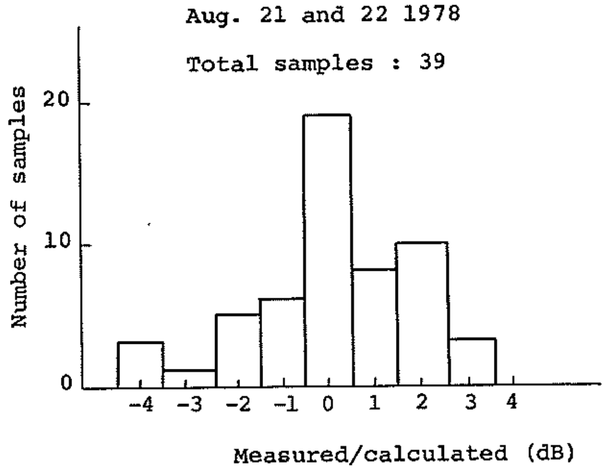

Figure 12 Deviation of received power from calculated value

2.2 Solar noise interference

It is well known that the sun transits in a beam of a ground receiving antenna during the vernal and autumnal equinoxes, if the antenna points toward the geostationary orbit. A harmful interference can be happened to reception of satellite broadcasting at that case. Increase of noise was measured at several locations with antennas of different diameter.

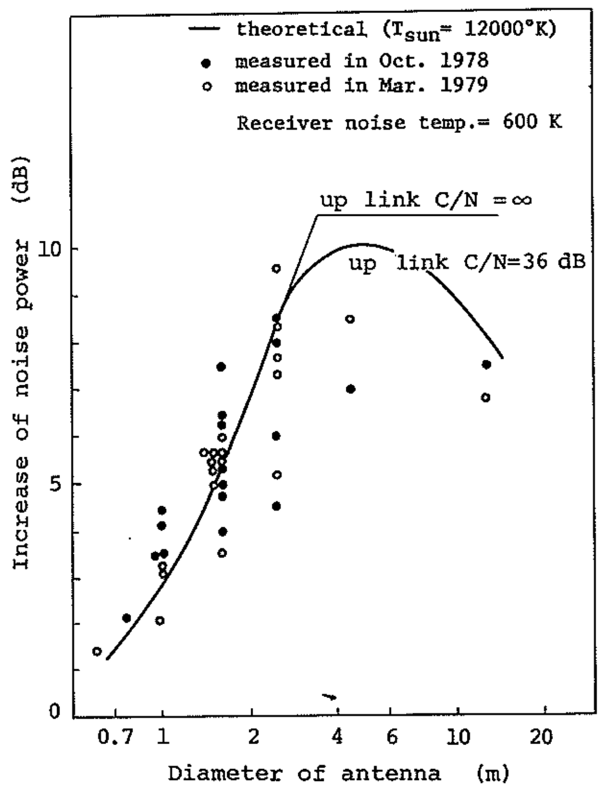

Figure 13 Increase of noise at receiver input due to solar noise interference

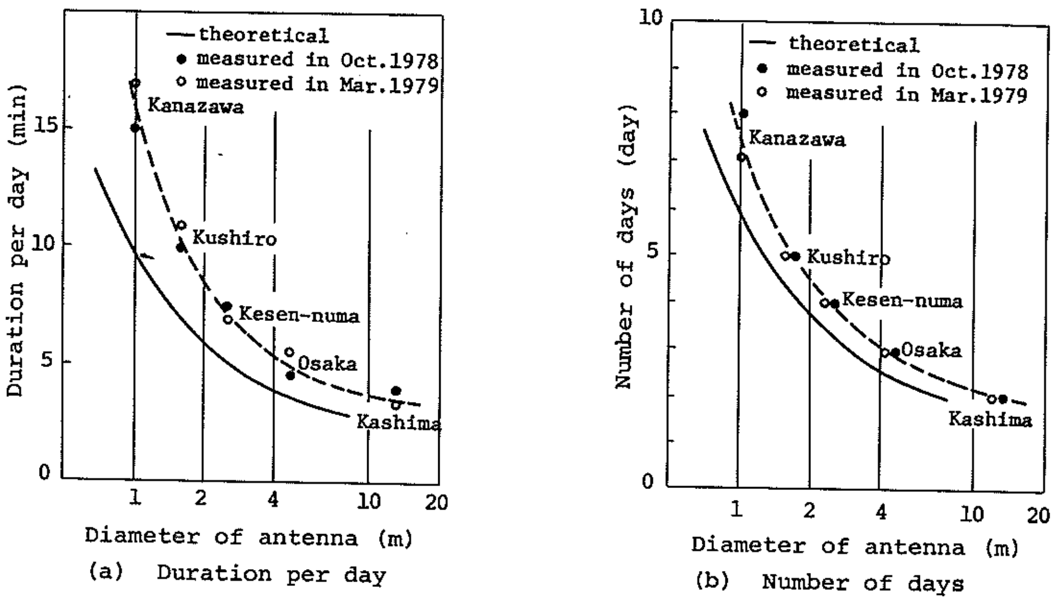

Figure 14 Duration and occurrance of solar noise interference

Figure 13 shows increase of noise power due to the solar noise interference at a receiver, of which noise temperature is about 600 K.

Figure 14 shows duration time of the possible solar interference per day and number of days of its occurrence. In comparison of these results with the rain attenuation statistics, it is understood that the solar noise interference affects the satellite broadcasting service only for much smaller percentage of the time than rain attenuation does, and moreover occurrence time and intensity of the interference can be predicted with practical accuracy.

V. Conclusion

The analysis of the propagation measurements has revealed preliminary but interesting results on statistics of rain attenuation at various locations of Japan, which would lead to final fruitful results at the end of the experiment for the expected full three years, besides an efficient method for eliminating the non-propagation effects from obtained data.

By the TV-reception tests, it has been confirmed that received power was generally coincided with the prediction and also that excellent quality of picture was obtained at each location all over Japan. The solar noise interference was realized to affect satellite broadcasting service only for much smaller percentage of the time than rain attenuation does.

Influence of show, especially fall of wet snow on a receiving antenna causes severe degradation of reception. It is needed keenly to clarify its mechanism and statistics and develope a method for improvement.

Acknowledgement

The authers wish to express their thanks to the staffs of RRL and NHK for collaboration and asistance in performing the experiment, as well as to the personel of NASDA for tracking and control of the BSE.

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