VOLUME 11

NUMBER 58
Printed in Tokyo, Japan
pp. 363-376

JOURNAL

OF THE

RADIO RESEARCH LABORATORIES

NOVEMBER 1964

UDC 621.396.946: 621.397.13

OLYMPIC TV TRANSMISSION VIA SYNCOM III SATELLITE

By

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ABSTRACT

The Olympic TV transmission via SYNCOM III satellite was successfully carried out over the Pacific Ocean. This paper describes the system of the Olympic TV transmission and some results of associated tests, emphasizing that the orbit and altitude of the SYNCOM III satellite were splendidly controlled and also that the techniques developed for improving the signal-to-noise ratio were really effective.

1. Introduction

The television of the 18th Olympiad at Tokyo was successfully transmitted via the SYNCOM III satellite over the Pacific Ocean, marking great meaning in the histry of satellite communication.

The SYNCOM III satellite, launched from Cape Kennedy on 19 August, 1964, reached the International Dateline around 10 September. The Kashima Earth Station caught the beacon signal of 136 Mc about 80 minutes later than the launching and continued the tracking. On 12 September, the TV transmission test was commenced through the loop circut of Kashima-SYNCOM-Kashima. On 1 October, when the Point Mugu Earth Station was completed, the test was changed to that from Japan to U.S.A., the result being that the quality of TV picture received was very good. Thus, the TV transmission of the Olympiad was successfully accomplished.

This sensational demonstration of the satellite communication was carried out on a basis of the contracts established between COMSAT, NHK, NBC and EBU on 23 July, 1964, and the members participated were COMSAT, NASA, the U.S.

Defence Department, NBC, CBS, ABC, HAC (Hughes Aircraft Company) in U.S.A., CBC in Canada, EBU in Europe and the Ministry of Posts and Telecommunications, NHK (Japan Broadcasting Corporation), RRL (Radio Research Laboratories), RRB (Radio Regulatory Bureau), KDD (Japan's Overseas Radio and Cable System), NTT (Nippon Telegraph Public Corporation) and NEC (Nippon Electric Company) in Japan.

Here are presented an outline of the system of the Olympic TV transmission and also some noteworthy results obtained from the associated measurements with regard to the SYNCOM III's orbit and the signal-to-noise ratio of TV picture.

2. TV Transmission System

2.1. Video signal transmission lines

The block diagram of the transmission system of TV signals (video and audio) is shown in Fig. 1. The video signals were sent from the Olympic stadiums to the NHK TV Center at Yoyogi, Tokyo, where bandwidth compression of video signals and modification of synchronizing pulses were performed. The processed signals were transmitted to the Kashima Earth Station through three successive 7 Gc-links via Koganei and Tsukuba. The Kashima Earth Station is located near the Pacific Ocean, about 90 km in the east of Tokyo. A 2 Gc-link, used as auxiliary, was set between Koganei and Kashima. At Kashima, the video signals were transmitted to SYNCOM III from a 7359 Mc 10 kW transmitter by use of a 10 m Cassegrainian antenna.

The TV-signal of 1812 Mc retransmitted from SYNCOM III was received by a 26 m paraboloidal antenna at the point Mugu Earth Station near Los Angeles,

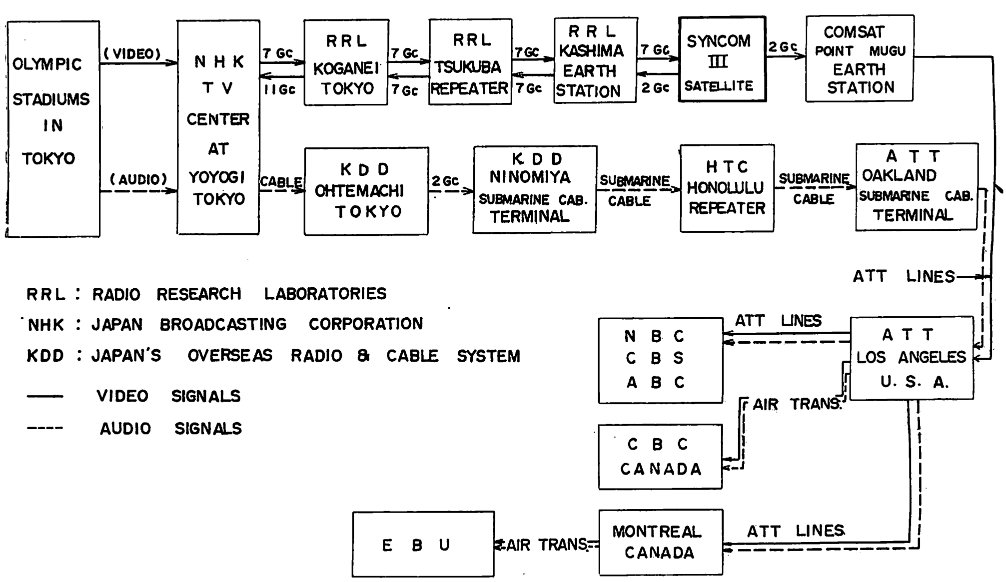


Fig. 1. TV transmission system of the 18th Olympiad via SYNCOM III satellite.

California, where the signals were demodulated into the video signals and distributed to U.S.A., Canada and Europian countries. EBU took VTR at Montreal, Canada, and sent it by jet to Europe.

On the other hand, the signals of 1812 Mc (TV) re-radiated and 1820 Mc (beacon) emitted from SYNCOM III were also received at Kashima by a 30 m Cassegrainian antenna for monitoring and antenna-pointing, respectively. The TV signals received here were sent through 7 Gc and 11 Gc links back to the NHK TV Center at Yoyogi for the purpose of monitoring at NHK.

2.2. Audio signal transmission lines

The audio signals were transmitted from the Olympic stadiums to U.S.A., as shown in Fig. 1, through the submarine cable which was completed on 19 June, 1964.

The audio signals were sent also to Kashima via 13 Gc links, relayed at Tsukuba, so that the simultaneous transmission of video and audio signals via SYNCOM III might be provided by using a voice-modulating adapter at Kashima. A 600 Mc links was arranged between Koganei and Kashima for auxiliary use.

2.3. Supporting communications lines

The supporting communications lines were prepared as follows:

(1) Telephone lines between Kashima, Yoyogi and Point Mugu,

(2) Telephone lines between Kashima, Koganei and Yoyogi,

(3) Telex system between Kashima, Koganei, Point Mugu and Washington.

The telex system was used for exchange of the experimental schedules, test procedures, SYNCOM's orbital data and so forth.

2.4. Facilities at earth station

At the Kashima Earth Station, a 10 kW transmitter and a 10 m Cassegrainian antenna were installed for transmission of 7359 Mc signals. The transmitter has a four-cavity Klystron VA-863 B in the last stage of power amplifier. The 1812 Mc and 1820 Mc signals from SYNCOM III were received by the 30 m Cassegrainian antenna for monitoring of transmission and antenna-pointing, respectively. The receiver has a liquid-nitrogen colled parametric amplifier which lowers the system noise temperature down to about 75° K. The antennas are shown in Fig. 2, where the left and right are for transmitting and receiving respectively.

At the Point Mugu Earth Station, the 1812 Mc and 1820 Mc signals were received by the 26 m parabolic antenna and fed to a MASER preamplifier. The system noise temperature was measured so low as less than 40° K. The outside view of this station is shown in Fig. 3.

The pertinent data to the above facilities are summarized in Table 1.

2.5. Special systems developed for Olympic TV transmission

Prior to the TV transmission tests, the carrier-to-noise ratio in the over-all circuit from Kashima to Point Mugu via SYNCOM III was evaluated as about 9.1 dB, as shown in Table 2, where the SYNCOM III satellite was assumed to be located over the International Dateline. Consequently, the signal-to-noise ratio of TV picture received at Point Mugu was estimated as about 22 dB, if a convention-

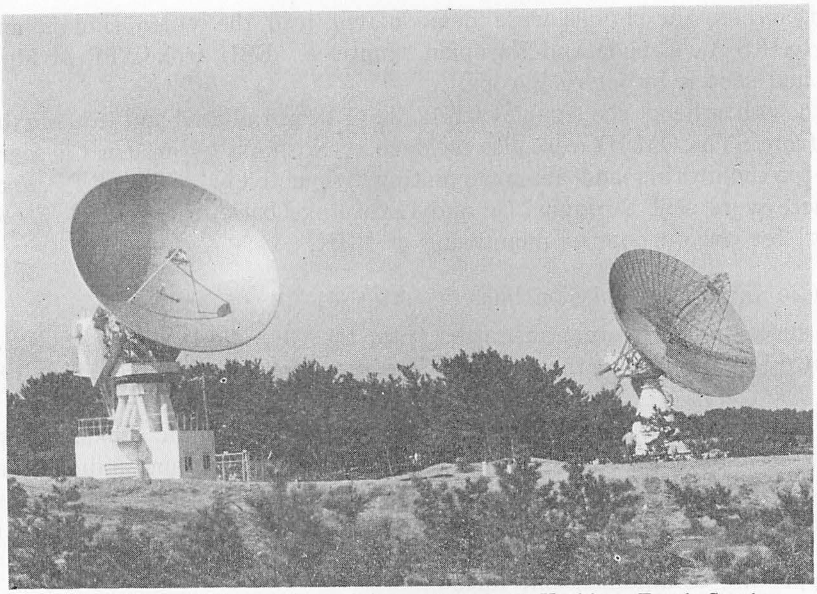


Fig. 2. Transmitting and receiving antennas at Kashima Earth Station.
(Left: 10 m cassegrainian antenna for transmitting.)
(Right: 30 m cassegrainian antenna for receiving.)

al system were used. Such poor signal-to-noise ratio like this, needless to say, was not sufficient for TV broadcasting. It suggested that special techniques should be developed in improving the ratio by 10 dB or more. Thereupon, the following techniques were proposed by NHK and NEC:

(1) To modify the synchronizing pulse in TV signal,
(2) To utilize proper emphasis and video-amplitude compression,
(3) To compress the total frequency bandwidth of video signal.

The first one is modification of the synchronizing pulse into a positive-polarity one on which a 2 Mc (or 1 Mc) sinsoidal wave is superposed in order to make easy the descrimination of the pulse. This procedure improves the signal-to-noise ratio of TV picture by about 3 dB.

The second one intends to increase the effective amplitude of TV picture at the sacrifice of the high-frequency component. Improvement of the signal-to-noise ratio by this method is estimated as more than 10 dB.

The third one is the most attractive, but the device therefore is fairly complicated. Although the conventional TV signal is composed of odd- and even-numbered fields, this method uses only the odd-numbered fields. They are recorded on a helical-scanning VTR at the half of standard speed, the time-space for scanning the even-numbered fields being cancelled. By this procedure is obtained one-half bandwidth signal. This signal is fed to the modulator of the transmitter (at Kashima). At the receiving side (at Point Mugu), the signal is demodulated and again recorded on a helical scanning VTR at the half speed. The recorded signal is reproduced on another helical-scanning VTR running at the standard speed. The deficient portions of the even-numbered fields are replenished with the signals produced from the odd-numbered field by use of a delay equip-

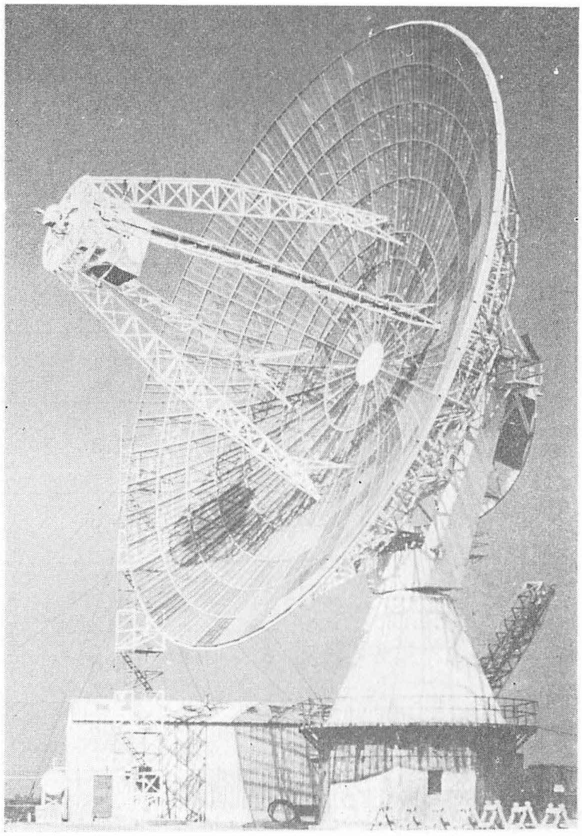


Fig. 3. Receiving antenna at Point Mugu Earth Station.

Table 1. Earth Station facilities for TV transmission via SYNCOM III satellite.

Site \ Item	Frequency (Mc)	Antenna Type	Antenna Diameter (m)	Antenna Gain (dB)	Antenna Beam-width (deg.)	Remarks
Transmission terminal in Kashima	7359.4232	Cassegrainian	10	55.0	0.3	Trans. power 10 kW
Monitoring terminal in Kashima	1812.2170 1820.1771	Cassegrainian	30	51.5	0.4	System noise temp.: approx. 75° K
Receiving terminal in Point Mugu	1812.2170 1820.1771	Parabola	26	51.2	0.5	System noise temp.: approx. 40° K

Table 2. Estimated values of carrier-to-noise ratio in TV transmissin links.

Item \ Link	KASHIMA-to SYNCOM	SYNCOM-to-KASHIMA	SYNCOM-to-POINT MUGU
Frequency (Mc)	7359.4232	1812.2170	1812.2170
Effective radiated-power* (dBm)	123.7	36.2	36.2
Distance (km)	38580	38580	40340
Basic transmission loss (dB)	202.2	189.4	189.8
Receiving antenna effective gain (dB)	0	51.3	51.2
Received signal level (dBm)	−78.5	−101.9	−102.4
Received noise bandwidth (Mc)	13	10	10
Receiver noise level (dBm)	−92.9	−109.6	−112.6
C/N (dB), Individual link	14.4	7.7	10.2
C/N (dB), KASHIMA-SYNCOM-KASHIMA	7.0		
C/N (dB), KASHIMA-SYNCOM-POINT MUGU	9.1		

Note: * Effective radiated-power from SYNCOM III includes an estimated loss of 0.3 dB due to the antenna beam pattern irregularity.

ment and an interpolator. Thus, complete signal is reproduced. The improvement of signal-to-noise ratio by this technique is expected as about 10 dB.

Although all techniques above-mentioned might be adopted to improve the signal-to-noise ratio, there still remain many factors to be considered: simplicity of equipment, reliability in operation, subjective quality of TV picture and so on. In order to find the best system, deliberate tests were needed prior to the program transmission of the Olympic Games. The results of these tests will be described in the later section.

3. Results of Experiment

3.1. Outline of experiment

At the Kashima Earth Station, the 136 Mc beacon-signal of the SYNCOM III satellite was received about 80 minutes later from the time of the launching of SYNCOM III on 19 August. Rough tracking was carried out since then. Precise tracking was added by receiving the 1820 Mc beacon-signal on and after 12 September, when the TV transmission tests were conducted in the looped configuration at Kashima. Since 1 October, the formal TV transmission tests were conducted between Kashima and Point Mugu. The result appeared that the quality of TV picture received at Point Mugu was much better than anticipated. Thus, the Olympic TV transmission was successfully accomplished.

At the opening ceremony on 10 October, the scenes were transmitted from main stadium for 1 hour and 45 minutes. The Game programs, were transmitted every day for NBC or CBS, CBC and EBU. Total hours of TV program transmission amounted to about 32 hours.

It is noteworthy that the transmissions were not available around 1200 (U.T.) for the period of 10 through 15 October due to the eclipse for the SYNCOM III.

3.2. Tracking of SYNCOM III

The SYNCOM III satellite, launched from Cape Kennedy at 1215 (U.T.), 19 August, 1964, was injected into the transfer orbit at 1241 (U.T.) on the same day. By successful apogee-moter boosting at 1717 (U.T.) on 20 August, it came into a drift orbit toward the International Dateline and reached there as a stationary satellite around 10 September.

The Kashima Earth Station caught the beacon signal of 136 Mc and traced the location of the satellite. The results are illustrated in Fig. 4 and 5: the former

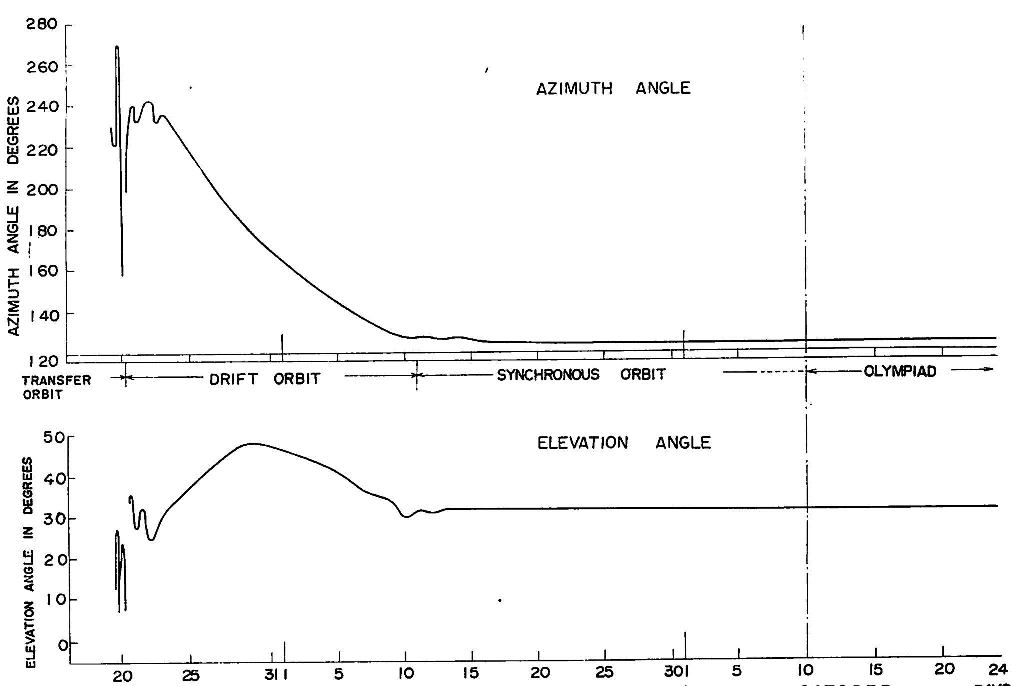


Fig. 4. SYNCOM III tracking data at Kashima Earth Station.

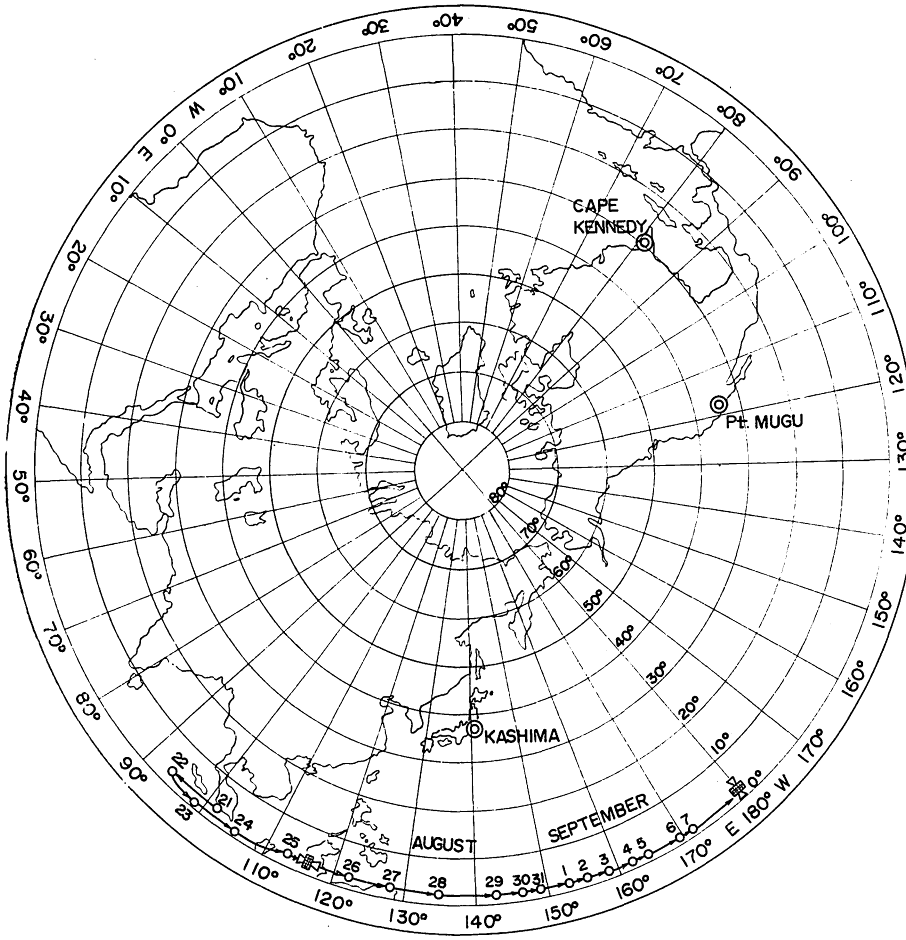


Fig. 5. Movement of SYNCOM III along the drift orbit.

indicates the azimuth and elevation angles, and the latter the trail of the satellite which was estimated from the data in Fig. 4. It can be seen that the orbit was successfully controlled to attain the final position and that SYNCOM III ran along the splendidly fine synchronous orbit after 15 September.

Another series of pointing data are shown in Fig. 6, which is based on the reception of the 1820 Mc beacon signal. The measurements were performed at 1100, 1400 and 2200 (U.T.) every day. For the sake of reference, the values predicted by NASA are also indicated in the figure. Noteworthy are the following:
(1) The variation ranges of elevation and azimuth angles were less than 0.05 degrees within a day and less than 0.2 degrees within 20 days.
(2) Distinct difference are found between the measured and predicted values on the day-to-day variations in the azimuth and elevation angles. Here, it should be noted that the measured values are accurate as far as the relative values are concerned. Simple analysis suggests that the anomalistic period of the SYNCOM

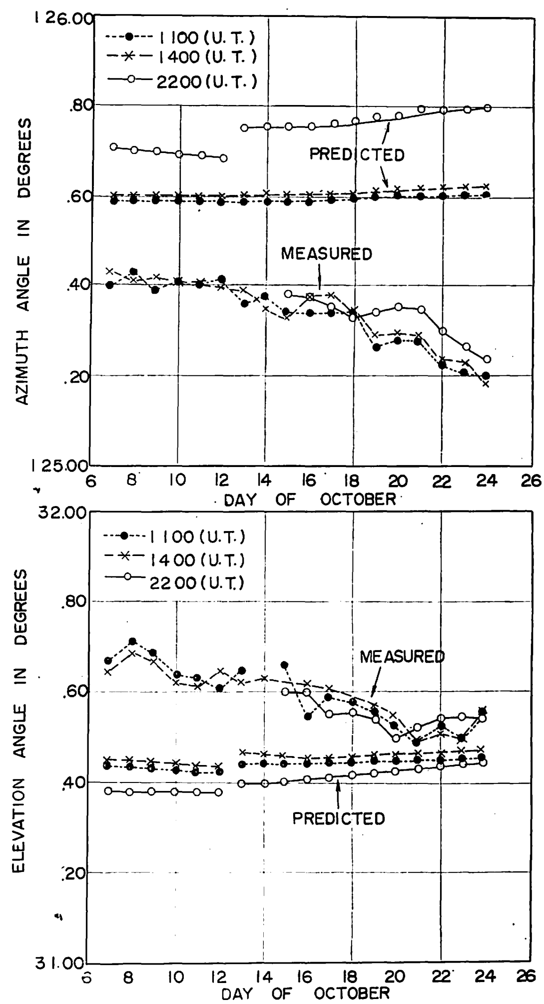


Fig. 6. Day-to-day variation in azimuth and elevation angles of SYNCOM III.

III satellite deduced from the observed data is about 0.18 minutes less than the period of 1436.22 minutes informed from NASA.

3.3. Signal-to-noise ratio of TV picture

As described in Subsection 2.5, comparative measurements were conducted in order to determine the best system of TV transmission, prior to the opening of the Olympiad. The results are indicated in Table 3. As was expected, the best signal-to noise ratio was obtained in the TV system No. 8, where the TV signals were transmitted at the rate of 30 fields per second with positive synchronizing pulses through the circuits of emphsis and amplitude-compression. In the practical program transmission, however, was adopted the system No. 4 in which the TV signals were transmitted at the rate of 60 fields as explained in the note below

Table 3. Signal-to-noise ratio of TV picture measured at Kashima and Posnt Mugu Earth Station.

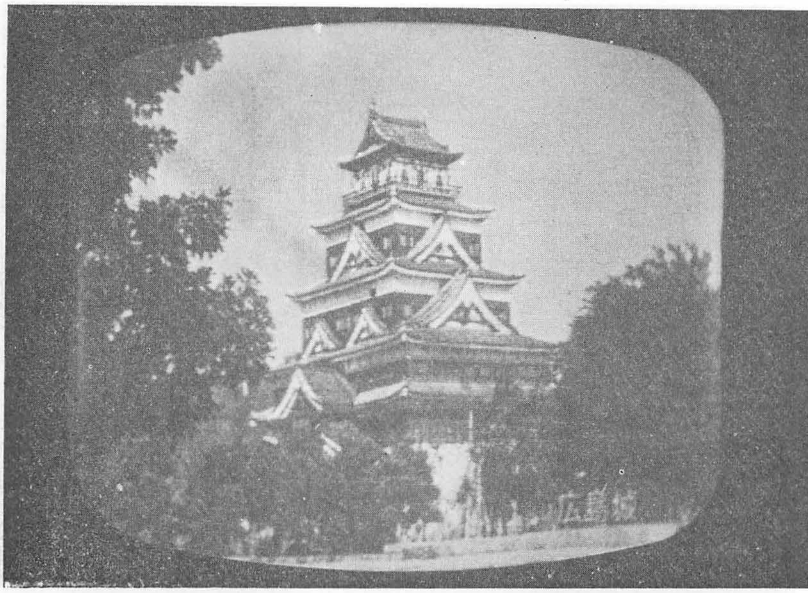
TV System	Trans-mitter power (kW)	Freq. devi-ation (p-p) (Mc)	Base-band Freq. (Max.) (Mc)	Empha-sis (dB)	At Kashima			At Point Mugu		
					C/N (dB)	S/N (dB)	No. of data	C/N (dB)	S/N (dB)	No. of data
No. 1	7	7	2.5	6	7.5	23.7	6	11	25	1
				12	7.7	24.9	6	12	27	1
No. 2	7	7	2.5	6	7.9	25.1	1	—	—	0
				14	7.6	27.8	1	—	32	1
No. 4	7	7	2.5	14	7.0	31.8	43	11	34	26
No. 8	7	8	1.25	12	8.0	33.5	3	11	38	1

Noter: (1) Definition of TV system
No. 1: 60 fields per second, negative synchronizing pulse,
No. 2: 60 fields per second, negative synchronizing pulse, amplitude compression.
No. 4: 60 fields per second, positive synchronizing pulse, amplitude compression.
No. 8: 30 fields per second, positive synchronizing pulse, amplitude compression.
(2) C/N indicated is approximate value, whice should be corrected with regard to the satellite noise.
(3) S/N is defind as a ratio of peak-to-peak video to unweighted RMS noise.

Toble 3. The reason why the system No. 4 was adopted is that the system No. 4 was more simple and more reliable in operation than the system No. 8 and also that the signal-to-noise ratio of the picture received at Point Mugu by the system No. 4 was considered satisfactory for the TV broadcasting.

Fig. 7 and 8 illustrate samples of TV picture which were observed at Kashima and Point Mugu by use of the system No. 4. It can be seen from these picture that the quality of picture was quite good.

As for the data shown in Table 3, attention should be paid to the following:
(1) The number of sample of data is disverse. Needless to say, the data of small sample-number is less reliable in accuracy.
(2) The measuring method of the signal-to-noise ratio at the Kashima Station was different from that at the Point Mugu Station. This effect becomes significant when the comparative analysis is made between the data obtained at the both stations.

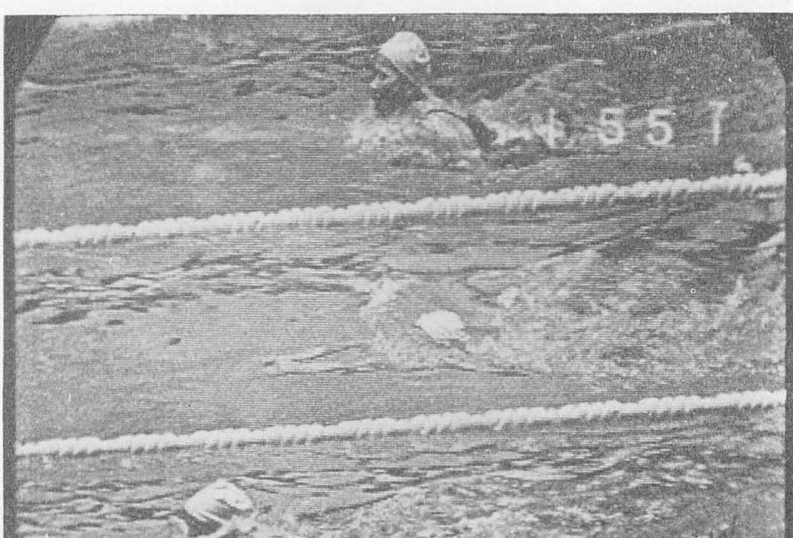


(a) Frequency deviation: 7 Mc (p-p), Baseband frequency: 2.5 Mc (Max.), Emphasis: 14 dB, C/N: 6 dB (Approx.), S/N: 30 dB (p-p/RMS, unweighted), TV system: No. 4, Date: Oct. 10, 1964.

(b) Frequency deviation: 7 Mc (p-p), Baseband frequency: 2.5 Mc (Max.), Emphasis: 14 dB, C/N: 5 dB (Approx.), S/N: 31 dB (p-p/RMS, unweighted), TV system: No. 4, Date: Oct. 10, 1964.

Fig. 7. Samples of TV picture transmitted through the loop circuit Kashima-SYNCOM-Kashima.

(a) Frequency deviation: 8 Mc (p-p), Baseband frequency: 2.5 Mc (Max.), Fmphasis: 14 dB, C/N: 12 dB, S/N: 36 dB (p-p/RMS, unweighted), TV system: No. 4, Date: Oct. 8, 1964.



(b) Frequency deviation: 7 Mc (p-p), Baseband frequency: 2.5 Mc (Max.), Emphasis: 14 dB, C/N: 12 dB, S/N: 35 dB (p-p/RMS, unweighted), TV system: No. 4, Date: Oct. 18, 1964.

Fig. 8. Samples of TV picture observed at Point Mugu Farth Station.

(3) The values of carrier-to-noise ratio listed in Table 3 are not correct because they include some errors due to the satellite noise. Simple analysis suggests that the true values of carrier-to-noise ratio may be about 1 dB less than those indicated in Table 3.

In order to know the relations between the carrier-to-noise ratio, the signal-to-noise ratio and the ratio and the radiated power, a series of power-reduction tests were carried out. The typical result is shown in Fig. 9 which was obtained in the TV system No. 4 at the Kashima Earth Station. It indicates that the degradation of the carrier-to-noise ratio was 2.1 dB when the transmitter output was reduced from 10 kW to 1 kW while that of the signal-to-noise ratio amounted to 6.2 dB in the same condition and also that, if one dB degradation of the signal-to-noise ratio is allowed, the transmitter power may be reduced from 10 kW to the half.

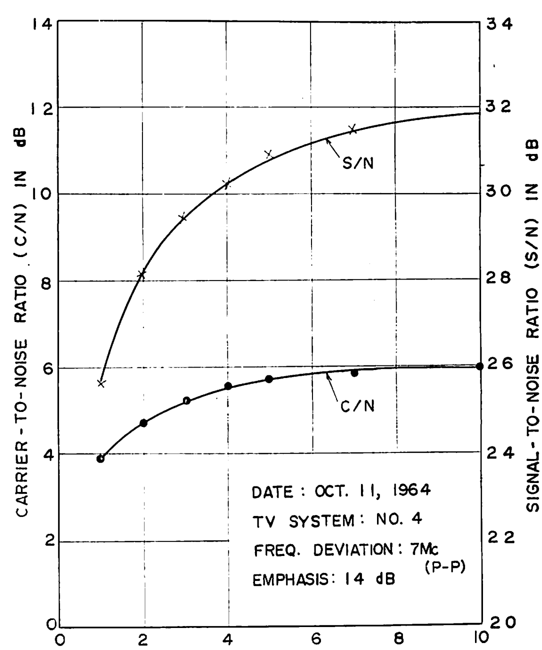


Fig. 9. Relation between carrier-to-noise ratio, signal-to-noise ratio and radiated power in loop circuit of Kashima-SYNCOM-Kashima.

4. Concluding Remarks

The TV transmission of the 18 th Olympiad at Tokyo was successfully achieved over the Pacific Ocean. On the data obtained by the associated measurements, the following are of noteworth:

(1) The orbit and attitude of the SYNCOM III satellite were splendidly controlled. Consequently, no readjustment of pointing of the antennas was needed for the

whole period of the Olympics, once it was made at the beginning. However, there was found a distinct difference between the predicted and measured values with respect to the antenna-pointing data for the long term.
(2) The quality of pictures reproduced at the Point Mugu Earth Station was very good. The techniques developed for improving the signal-to-noise ratio were really effective.