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Technical feasibility on reception of VHRR signals from Kalpana-1 satellite in the event of contingency with the existing operational ground receiving system

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सार – भारत मौसम विज्ञान विभाग का राष्ट्रीय उपग्रह मौसम केन्द्र राष्ट्रीय उपग्रहों की श्रंखला के कल्पना–1 / इनसैट द्वारा प्रेषित किए गए मौसम वैज्ञानिक आँकड़ों के संकेतों को प्राप्त करने तथा मौसम वैज्ञानिक, पर्यावरणीय एवं जलवायु स्थितियों का मॉनीटरन करने के लिए विभिन्न प्रकार के मौसम विज्ञानिक उत्पादों को तैयार करने हेतु आँकड़ों का संसाधन करने में महत्वपूर्ण भूमिका निभा रहा है। इस समय उपग्रह के संकेत मौसम भवन परिसर, नई दिल्ली में स्थित भारत मौसम विज्ञान विभाग के इनसैट भू–केन्द्र में लगाए गए 7.5 मी. व्यास के पैराबॉलिक डिश एंटीना के माध्यम से प्राप्त किए जा रहे हैं।

इस शोध पत्र में इस भू–केन्द्र में उपलब्ध छोटे व्यास (3.8 मी.) के पैराबॉलिक डिश एंटीना से कल्पना–1 के वी. एच. आर. आर. संकेतों को प्राप्त किया जा रहा है और उन्हें संसाधित करने का प्रयास किया गया है। अतिरिक्त 2 डी. बी. मार्जिन को दिखान के लिए सैद्धान्तिक रूप से आवश्यक लिंक कैलकुलेशन बनाए गए और उपग्रह से चित्र को ग्रहण करने के लिए वह प्रर्याप्त होंगें। हमने इस परिणाम की तुलना इस समय मौजूद 7.5 मी. व्यास के एंटीना के साथ भी की और यह पाया कि 3.8 मी. के एंटीना से प्राप्त किए गए उपग्रह के चित्रों की गुणवत्ता भी उतनी ही अच्छी है।

इस अध्ययन का उद्देश्य भारत मौसम विज्ञान विभाग में मौजूदा आधारभूत संरचना का उपयोग करते हुए इस समय विद्यमान 7.5 मी. व्यास के पैराबॉलिक डिश एंटीना में किसी आकस्मिक घटना को ध्यान में रखते हुए बैकअप एंटीना का प्रचालनात्मक रूप से तैयार रखना है।

ABSTRACT. National Satellite Meteorological Center (NSMC), of India Meteorological Department is performing the vital role of receiving signals of meteorological data transmitted by KALPANA-1/INSAT series of national satellites and processing the data to generate various meteorological products for monitoring meteorological, environmental and climatological conditions. The satellite signals are currently being received through a 7.5 m diameter parabolic dish antenna installed at INSAT Earth Station of IMD located at Mausam Bhawan Complex, New Delhi.

In this study an attempt has been made to receive and process the VHRR signals of KALPANA-1 through a smaller (3.8m) diameter parabolic dish antenna available at earth station .The link calculations have been made to show extra 2 db margin what is theoretically required and it will be sufficient for image capturing. We had also compared the result with existing 7.5m diameter antenna and observe that quality of satellite pictures received with 3.8m diameter antenna are also equally good.

The purpose of this study is to keep in operational readiness a backup antenna for the reception of KALPANA-1 in the event of any unforseen contingency with the existing 7.5m diameter parabolic dish antenna, using the existing infrastructure of IMD.

Key words – Effective isotropic radiated power (EIRP), Link Budget and VHRR.

1. Introduction

Earth station unit of satellite meteorology division is functioning since the launch of INSAT-2 series of indigenous satellites from 1992 onwards.This earth station was initially designed, developed and implemented as a project and commissioned by Space Applications Center Ahmedabad (ISRO). It has a 7.5m diameter X-Y mounted

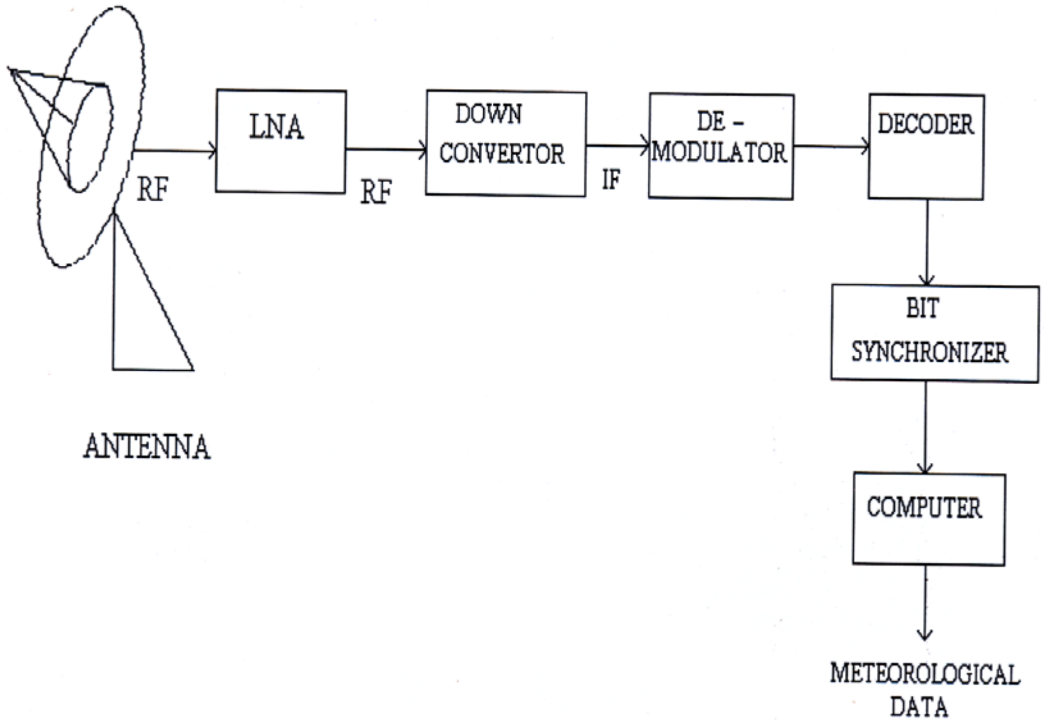

Fig. 1. Block schematic of ground receiving system

solid dish parabolic antenna having a cassegrin feed with a capability to receive meteorological data from the INSAT-2 series of satellites (INSAT-2A, INSAT-2B and INSAT-2E).The earth station also had a capability of transmitting processed cloud imageries data to the S-band transponders onboard INSAT for broadcast over the Indian region. Due to some technical reasons, this antenna is being used for reception purpose only for INSAT signals in extended C band around 4.5GHz since last more than 10 years. This antenna had been modified later on for the use of INSAT-1D reception in May 2002, subsequently this earth station was again put up in use for VHRR signal reception of exclusive meteorological satellite KALPANA-1 (METSAT) in September, 2002 and till date we are receiving the VHRR signals of Kalpana-1 for our day-to-day operational meteorological services.

Considering the need for keeping in operational readiness, another backup antenna for reception of VHRR signals from KALPANA-1 in the event of any unforseen contingency with existing old 7.5m diameter antenna at earth station, we have made an attempt to use a 3.8 meter diameter parabolic dish antenna with prime focus feed which was spare and it was being used basically as a test antenna for reception of data from automatic rain gauges (ARG) in collaboration with SAC, Ahmedabad. The purpose is to keep it as a backup antenna for reception of VHRR signals in case of any emergency due to any unforeseen reasons.

Keeping in view the results of on orbit testing of KALPANA-1, where it was shown that the measured EIRP of VHRR transmitter is 3dB better than the specification. An attempt had been made to receive VHRR data in addition with DRT signals with 3.8 meter diameter parabolic antenna. This was thought to be technically feasible due to availability of higher VHRR EIRP from the satellite.

As per theoretical calculations we expect a 2db margin in the overall link .For reception of VHRR signals from KALPANA-1 using 3.8m-diameter antenna this has been actually demonstrated in the present study. As a result of this the problem of availability of backup arrangement has been solved using the existing equipments in the department.

2. Necessity for using 3.8m Antenna in IMD for reception of KALPANA-1 VHRR

The backup requirement for INSAT-3A satellite data reception in IMD is already complete. Antenna currently in use are 6.1 m diameter parabolic dish antenna for

IF (KALPANA – I)

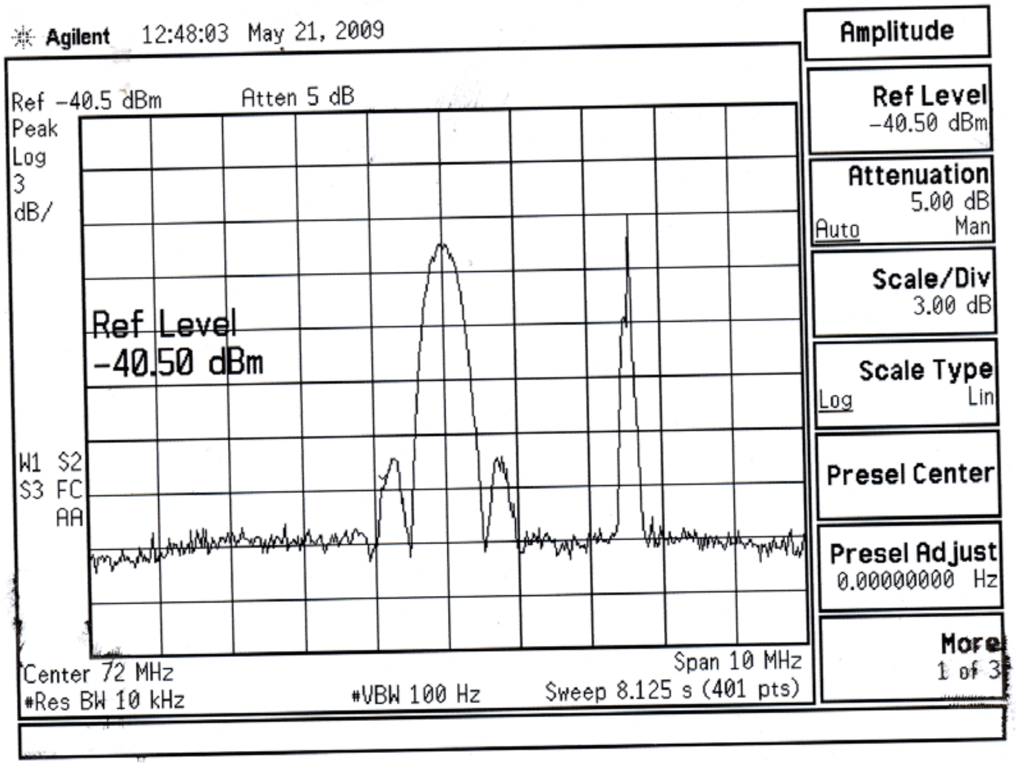

Fig. 2. IF spectrum of Kalpana-1 VHRR signal with 3.8 Antenna

RF (KALPANA – I)

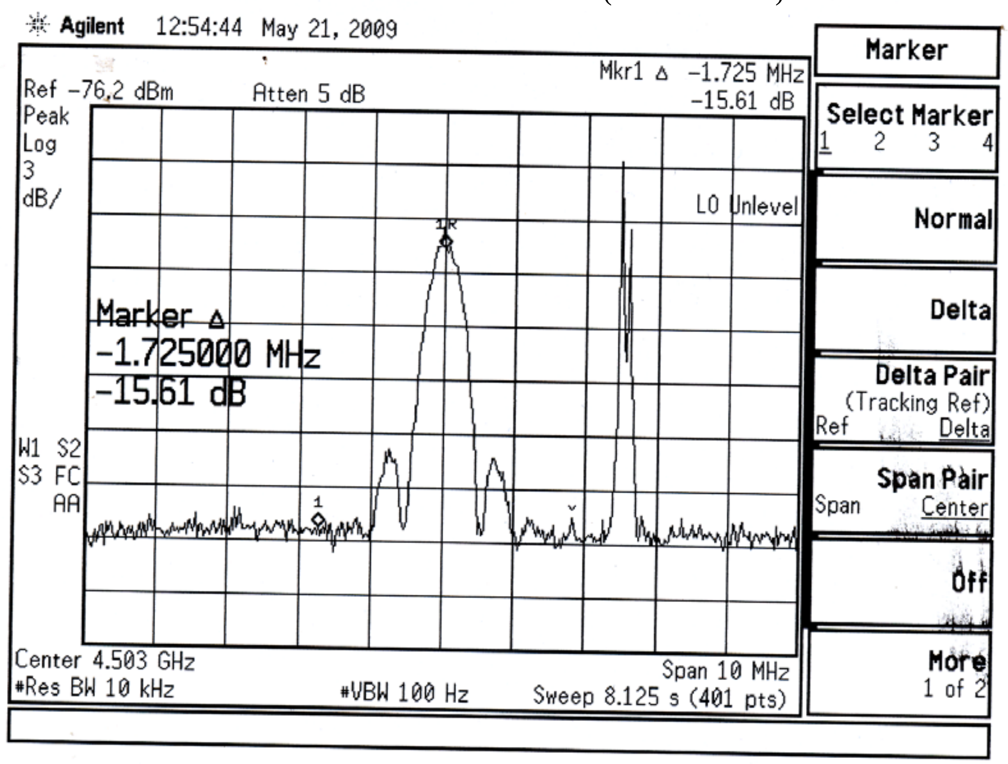

Fig. 3. RF spectrum of Kalpana-1 VHRR signal with 3.8m Antenna

Fig. 4. Sampled Gray level pixel comparison of 3.8 and 7.5-meter antenna (0800 UTC on 23 June 2009)

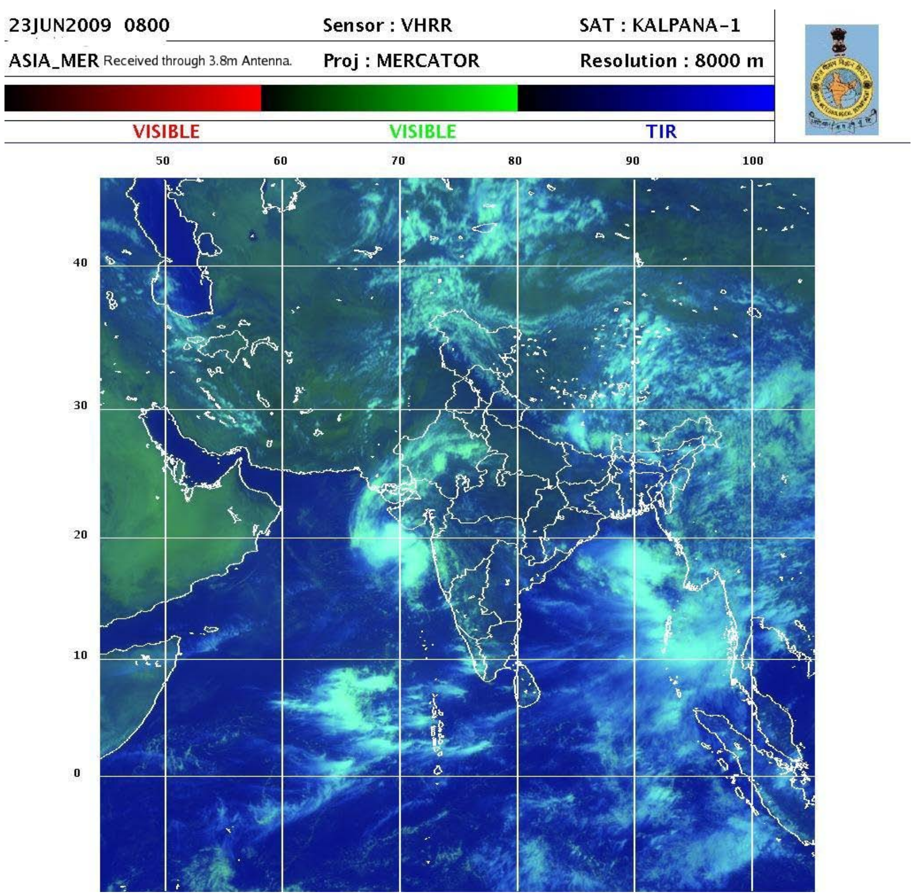

Fig. 5. Image received through 3.8 meter Antenna

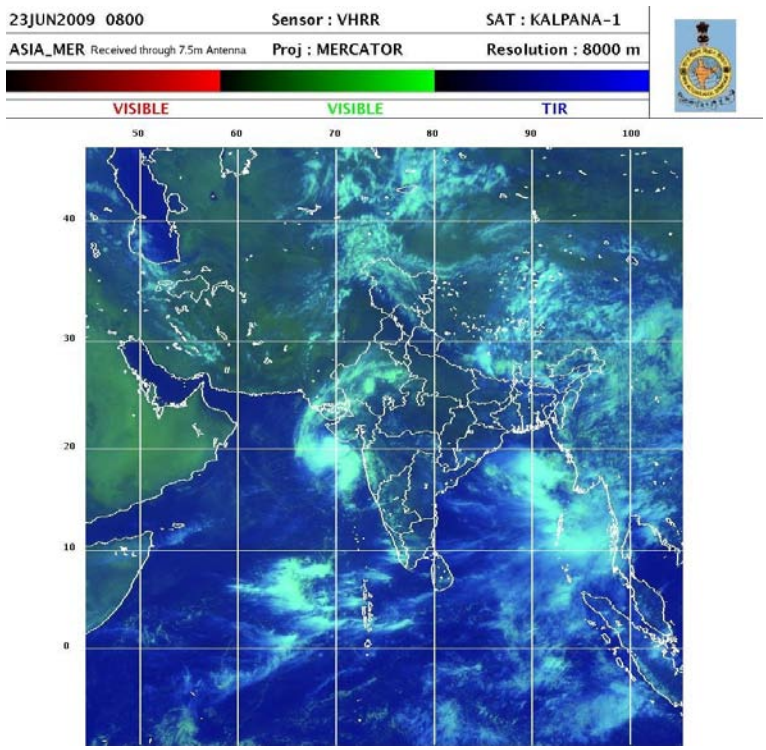

Fig. 6. Image received from 7.5 meter Antenna

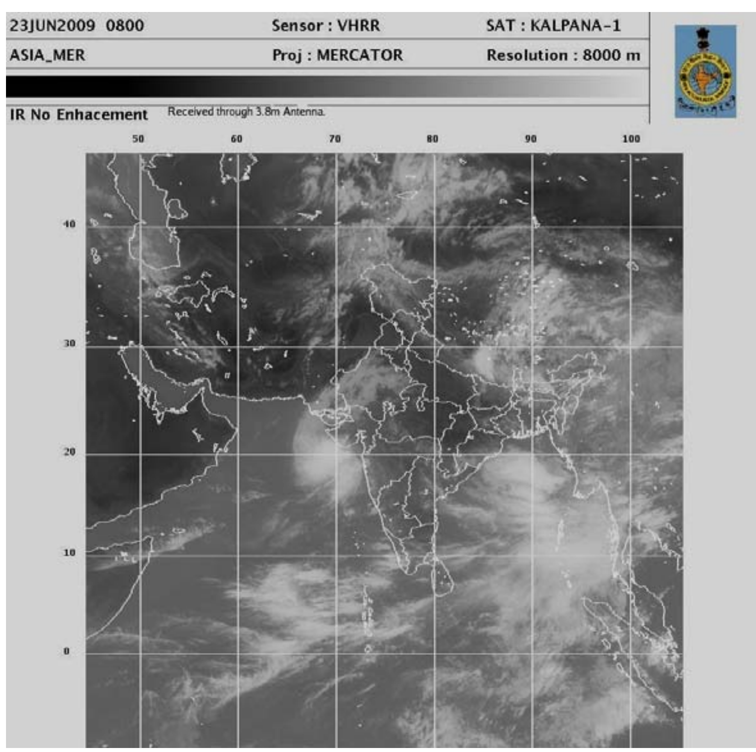

Fig. 7. Image received from 3.8 meter Antenna

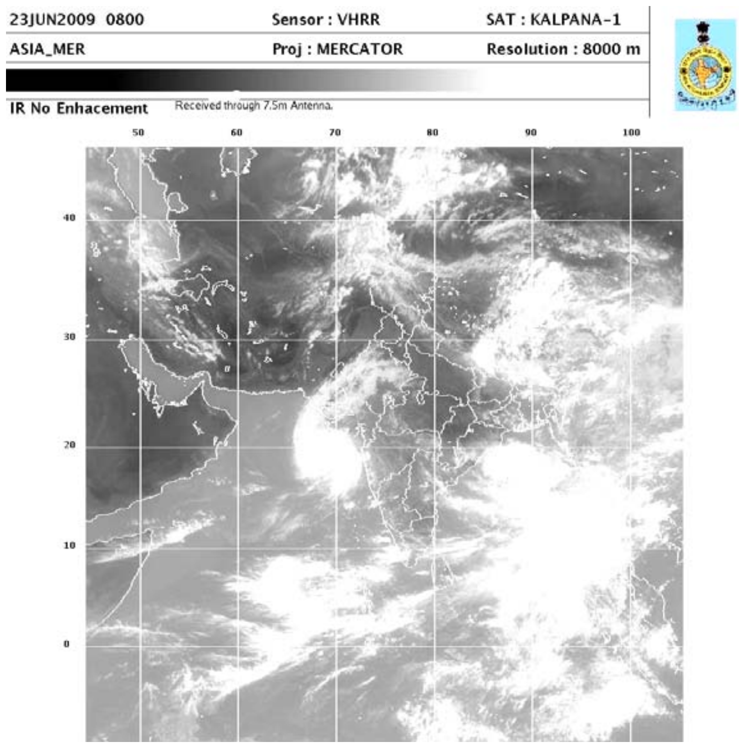

Fig. 8. Image received from 7.5 meter Antenna

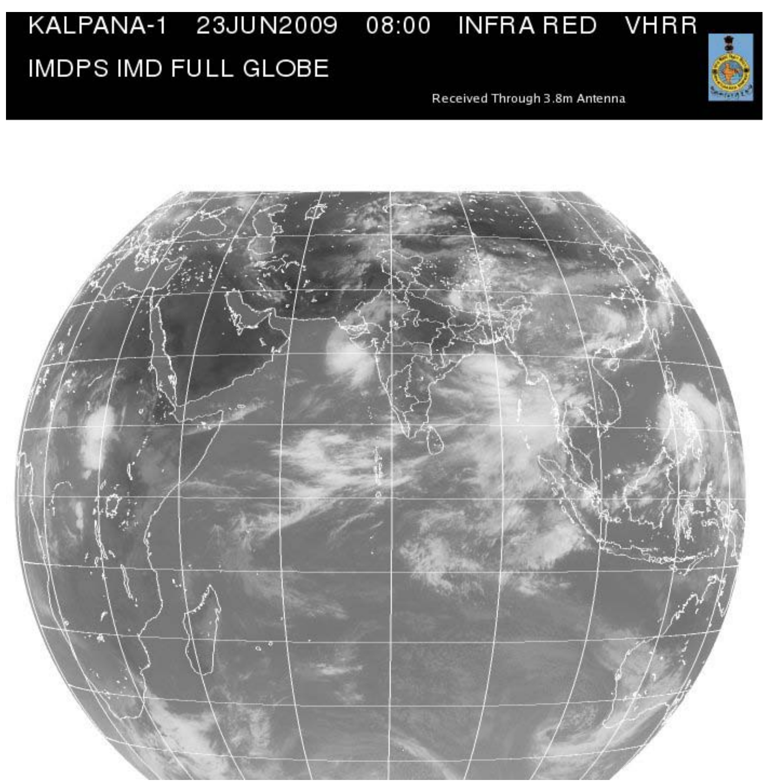

Fig. 9. Image received from 3.8 meter Antenna

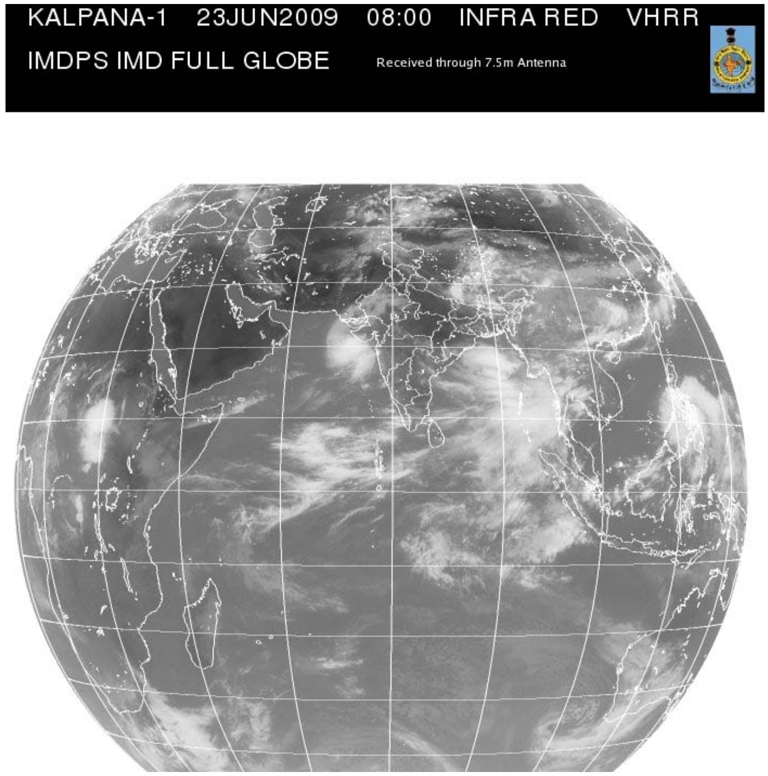

Fig. 10. Image received from 7.5 meter Antenna

reception of INSAT-3A signal with a backup up of 6.3 m parabolic dish antenna. We have observed that the KALPANA-1 satellite performance is better than that of specification (EIRP of METSAT) and we get an extra 3dB power in the VHRR which can be usefully exploited for reception of VHRR signal from KALPANA using a smaller antenna size of 3.8 meter. Keeping this in view, we have explored the technical feasibility of using 3.8m diameter antenna as a backup for KALPANA-1 VHRR with existing infrastructure.

3. Theoretical analysis of signal reception

RF signal of –150dBm is received through 3.8m diameter parabolic dish antenna with a prime focus feed and is fed to LNA unit having noise temperature of 90 deg.K and 60 dB gain. This RF signal is further down converted to generate 70 + -20 MHZ IF. There is a dual conversion inside the demodulator with a first local oscillator (5.58-5.88 GHz) and second local oscillator (1150 MHz). Thereafter, it is demodulated from the carrier 4503.5 MHz of Kalpana VHRR having data rate of 526.5 kbps. The data received is in the form of RS-422 compatible electrical signal. The signals received are differential clock and differential data which is converted to TTL form. VHRR is a BPSK modulated NRZ-S encoded signal with a bit rate of 526.5 kbps for input to Bit synchronizer for onward processing through main computers for generation of satellite imageries.

For 3.8 meter diameter antenna the technical parameters like, G/T of earth station, Antenna gain, Eb/No, have been calculated and compared with the ideal characteristics of extended C band antenna of 7.5 m diameter which is shown in Appendix.

An extra margin of 2.0dBHz as shown in Appendix is obtained from the available 3.8m diameter parabolic dish antenna to receive the VHRR signal from Kalpana-1 satellite.

The RF/IF spectrum of KALPANA-1 VHRR signal with 3.8m diameter antenna is shown in the Fig. 2 and Fig. 3 respectively which were taken on 21 May 2009.

4. Operations in the inclined orbit mode with 3.8 meter antenna from tracking point of view

Tracking is necessary when the satellite goes in inclined orbit after end of life (EOL) of satellite when

TABLE 1

Sample digital data received by 3.8 meter Antenna (0800 UTC on 23 June 2009)

North-south station keeping manoeuvres stopped by MCF, Hassan. There is natural variation in the inclination of satellite, which gets increased at the rate of 0.8 degree per year after N-S station keeping manoeuvres operators are ceased by MCF. This necessities tracking of the satellite by the ground station antenna.

The autotracking facility is only available with INSAT-3A parabolic dish antennas (6.1m and 6.3m). There is no auto-tracking facility available in KALPANA-1 with existing 7.5-meter antenna. Therefore manual tracking will have to be done for reception of signals in the inclined orbit mode of operation as and when it takes place in future. Similar arrangements with 3.8-meter antenna will also be required.

The manual tracking in case of 3.8-meter antenna will be easier in comparison with 7.5-meter existing antenna for reception of KALPANA-1 VHRR signals because of the higher beam-width of 3.8-meter antenna. However, 3.8-meter antenna will take more time to come out of sun outage as and when it takes place. Degradation of signal due to the effect will be very nominal.

5. Comparison between theoretical and actual practical expectation

For a comparison of the quality of satellite images [Fig. 5 - Fig. 10], simultaneous processing by both 3.8m and 7.5m antennas had been done for three continuous days round the clock from 21 June 2009 to 23 June 2009.

TABLE 2

Sample digital data received by 7.5 meter Antenna (0800 UTC on 23 June 2009)

TableView - VHRR_TIR - /VHRR/Image Data/ - /nas/HDFProducts/K1VHR/2009/JUN/K1VHR_23JUN2009_0800_L1B_STD.h5 Received through 7.5m Antenna

Table

930, 809 580

	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824
927	570	572	571	573	573	576	583	577	575	575	578	581	582	575	573	573
928	576	580	575	572	575	573	575	580	578	575	575	578	579	577	575	574
929	580	584	586	579	571	575	576	579	581	579	575	576	580	580	578	575
930	578	579	580	584	575	574	575	578	578	577	576	575	578	583	580	578
931	574	574	576	578	574	576	575	578	583	582	573	576	579	578	577	583
932	569	570	570	569	570	577	581	576	577	579	571	572	576	582	580	577
933	570	572	570	571	570	572	579	583	574	573	577	574	577	579	579	578
934	573	571	570	569	570	570	572	575	580	578	576	574	578	578	578	577
935	570	570	569	567	568	569	569	570	574	578	581	574	572	575	575	587
936	566	567	565	565	567	566	565	567	570	572	570	573	570	572	571	576
937	564	567	566	565	565	565	564	565	569	568	571	574	576	569	572	575
938	568	568	567	568	568	567	566	567	568	570	573	576	574	574	573	576
939	570	570	568	568	567	569	569	568	573	574	578	576	577	577	573	575
940	571	568	568	568	565	567	570	570	572	572	572	575	580	578	574	572
941	570	567	565	566	566	567	568	569	573	576	570	571	571	571	576	578
942	569	567	565	566	569	572	572	571	570	571	571	572	571	573	577	576
943	568	570	565	566	567	570	568	567	566	567	569	570	572	577	579	578
944	567	569	567	567	573	571	567	567	569	569	571	572	574	587	584	583
945	565	566	569	579	573	568	567	567	571	574	583	582	589	592	583	593
946	567	570	574	575	570	572	567	575	590	587	576	572	582	589	587	591
947	575	579	575	573	570	574	573	575	595	602	587	579	585	600	597	589
948	581	587	580	584	581	577	579	577	586	603	589	586	591	596	601	588
949	575	580	581	583	586	585	590	577	580	583	595	601	604	601	587	582
950	583	590	597	599	591	585	579	578	593	600	601	609	594	602	590	573
951	607	605	590	600	602	581	573	583	598	589	576	588	584	568	571	569
952	609	617	593	587	605	601	585	581	586	579	573	573	572	570	571	573
953	580	605	607	600	594	598	588	583	597	587	568	567	569	570	570	570
954	579	584	606	609	602	604	599	611	608	587	571	568	569	568	569	570
955	588	599	590	595	593	581	580	596	610	593	568	568	568	570	570	569
956	585	592	599	610	600	581	575	588	584	573	569	569	568	569	568	570
957	600	588	586	613	619	607	596	572	573	571	571	571	570	571	573	574
958	621	620	619	622	626	618	611	579	571	571	573	572	571	573	575	574
959	623	610	616	624	609	592	582	575	569	570	571	570	571	573	574	573
960	623	625	599	584	580	575	573	570	568	569	572	570	571	572	574	573
961	601	593	589	581	585	587	574	571	571	570	569	570	572	573	574	579
962	591	581	579	579	591	586	578	575	579	578	571	570	572	571	580	599
963	589	581	587	605	608	583	578	581	582	573	573	573	572	574	581	601
964	619	619	609	617	616	589	575	584	583	586	603	607	593	580	583	589
965	624	612	622	620	596	583	573	572	576	581	590	589	600	610	586	579
966	612	605	610	604	584	575	574	575	579	581	577	576	582	585	579	581
967	597	583	593	593	575	577	578	580	586	585	579	576	578	579	594	595
968	582	583	595	595	580	579	579	579	583	604	596	584	587	583	589	590
969	578	582	581	578	578	587	586	585	603	623	617	612	615	599	596	599
970	575	578	575	575	586	582	581	589	592	604	624	625	620	619	608	597
971	575	578	575	575	578	583	582	586	591	606	602	604	616	595	598	622
972	590	579	576	575	578	577	575	577	587	583	582	595	599	600	614	623
973	591	589	592	584	577	577	576	576	579	586	584	584	583	595	610	609
974	595	609	609	594	580	578	578	578	577	598	600	593	598	618	622	601
975	601	619	630	626	608	593	581	575	581	595	594	610	621	599	600	593
976	585	614	618	618	624	598	581	577	577	578	585	613	618	595	584	580
977	586	598	599	595	604	594	579	575	577	579	592	617	611	579	580	580
978	582	602	600	587	597	597	596	584	578	579	585	608	600	579	579	580
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The Sample digital data (Gray value *vs* Pixel) by both antenna received at 0800 UTC of 23 June 2009 and the raw data is almost identical which is shown in Table 1 (3.8m Antenna) and Table 2 (7.5m Antenna).Gray level pixel comparison for the data received by 3.8 and 7.5-meter antenna is shown in Fig. 4. This digital data have been processed further with identical processing system in real time to derive the satellite imagery and related meteorological products. The quality of the satellite products and imageries by both the antennas are identical. There is no degradation in the quality of images with reduced antenna size. With reduced Eb/No [16.7] of 3.8meter antenna the quality of satellite images is same as that with the Eb/No [21.0] of 7.5meter antenna.

The backup chain with 3.8m antenna has been tested for an extended period of time (one week) and the reception of meteorological data have been found to the excellent.

6. Conclusion

The possibility of using smallest available (3.8m diameter) parabolic dish antenna at earth station unit has been explored for reception of KALPANA-1 VHRR satellite signal in the event of contingency .The quality of received image had been compared with the operational 7.5m diameter parabolic antenna. This 3.8 m diameter antenna had been made ready to receive the signal during any failure of 7.5m operational antennas and it is made as a backup antenna for reception of KALPANA-1 satellite signal at the earth station of India Meteorological Department, Mausam Bhawan, New Delhi. This backup arrangement has been actually demonstrated to work practically for reception of VHRR signal from KALPANA-1.

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Appendix

(a) G/T (figure of merit) of earth station had been calculated using gain equation and system noise temperature *i.e.*,

G/T = G – 10log (T system)

(b) Antenna gain, A(db) = 10 log $\eta[(3.14)\ D/\lambda]^2$

Where

D = antenna diameter

λ = wave length

η = 0.55(antenna efficiency).

since

$C = F \times \lambda$

where

$C = 3 \times 10^{10}$ cm/sec

$F = 4.5 \times 10^{9}$ per sec

and

D= 3.8 × 100cm = 380cm

Therefore

λ = 6.7 cm

Hence

$[(3.14)\ D/\lambda]^2 = 31697.5$

and

$\log\eta[(3.14)\ D/\lambda]^2 = 4.24$

Hence,

Antenna gain, A(db) = 10 × 4.24
= 42.4 db

This can also be verified from standard antenna gain and diameter graph as shown below in Fig. A1 [Wayne, 2006].

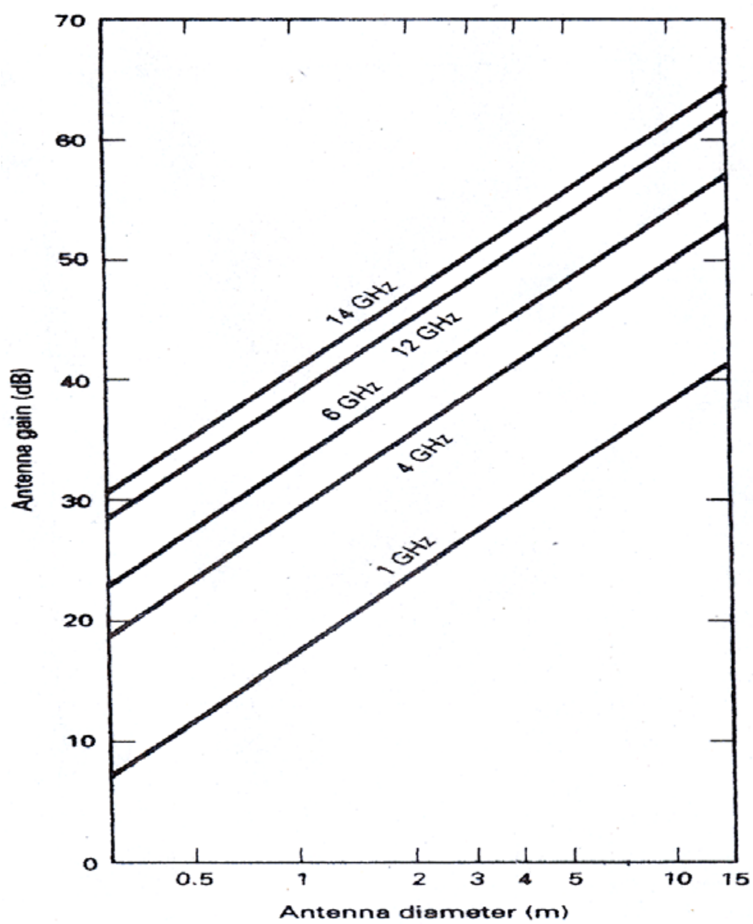

Fig. A1. Antenna gain as a function of antenna diameter for different frequency

(c) Free space path loss, Lp

Lp = 183.5 + 20 log f(GHz)

= 183.5 + 20 log(4.5)

= 183.5 + 13.06

= 196.56 dB

= 197 dB (approx)

Elevation angle correction at 56 deg (present location) =0.4dB(approx.) at a distance of 35930 km.

This can also be verified from standard plot (Fig. A2) as shown below

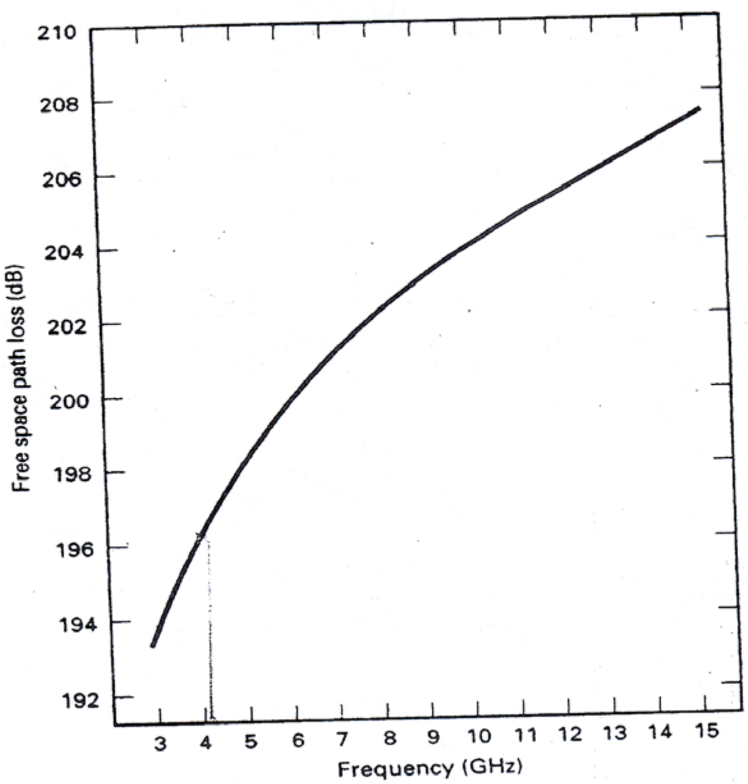

Fig. A2. Free space path loss (Lp) as a function of frequency

VHRR Data transmission system characteristics [METSAT Report, 2000]

(*i*) Transmit EIRP: 18.0dBW (EOL) as per document specification

(*ii*) Carrier modulation: BPSK

(*iii*) Carrier frequency assignment: 4503.5 MHz

(*iv*) Polarization plane: linear E- field vector parallel to space craft pitch axis vertical.

(*v*) EIRP stability: 1.0 dB p-p maximum over any operating day

(*vi*) Long term carrier frequency variation(life of satellite) : $\pm$40KHZ

(*vii*) Daily carrier frequency variation (excluding eclipse): $\pm$ 6KHZ

Link budget calculations for reception of VHRR signal using 3.8 meter diameter parabolic antenna

(*i*) Satellite EIRP: 18.0dBW

(*ii*) Free space loss at (4.5 GHz): 197.0dB (*iii*) Data rate: 526.5kbps/57.2dBHz

(*iv*) Eb/No required = 12.8db (from standard Fig. A3)

(*v*) C/No required: 70 dBHz (for Kalpana VHRR)

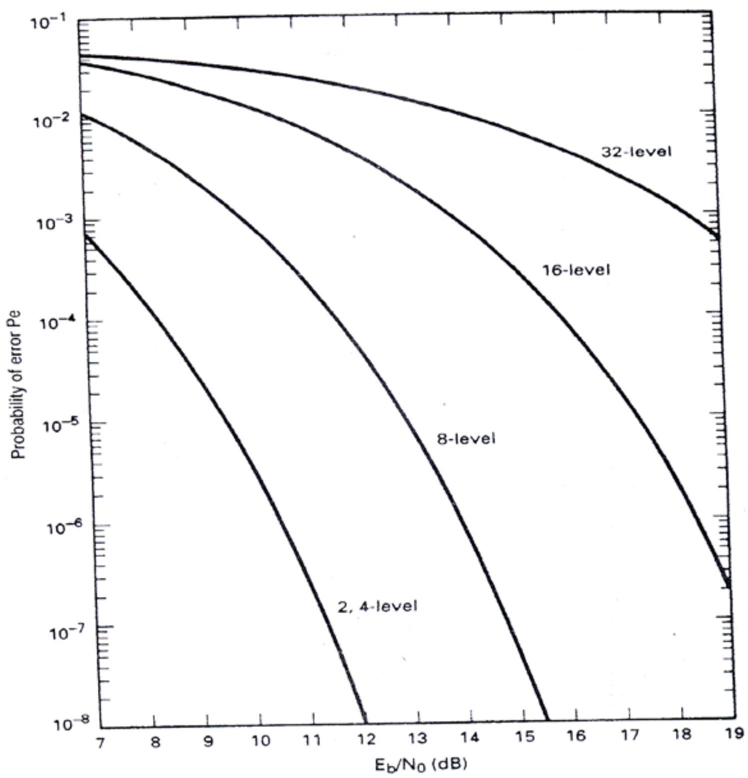

Fig. A3. Eb/No as a function of Error probability

Therefore

G/T for 3.8 m antenna will be

G/T = G – 10 log(Tsystem)

= 42.4 –20

= 22.4dB/deg. K

where (G antenna = 42.4dB and T system=100 deg. K at 5 deg. elevation up to Low noise amplifier) and

From the link budget equation,

C/No = EIRP-Path loss + G/T-K

= 18.0 –197 +22.4 + 228.6

= 72.0 dBHz

Required C/No is 70.0 dBHz

Therefore, the extra available margin in C/No for 3.8m antenna is 72.0-70.0 = 2 dBHz