# DATA HANDLING SYSTEM FOR IRS

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**Abstract:** The three axis stabilized Indian Remote Sensing Satellite will image the earth from a 904 Km polar - sun synchronous orbit. The payload is a set of CCD cameras which collect data in four bands visible and near infra-red region. This payload data from two cameras, each at 10.4 megabits per sec is transmitted in a balanced QPSK in X Band. The payload data before transmission is formatted by adopting Major and Minor frame synchronizing codes. The formatted two streams of data are differentially encoded to take care of 4-phase ambiguity due to QPSK transmission. This paper describes the design and development aspects related to such a Data Handling System. It also highlights the environmental qualification tests that were carried out to meet the requirement of three years operational life of the satellite.

**KEYWORDS:** IRS, Format, QPSK modulator, X band, BER, Link

## 1. INTRODUCTION:

The Data Handling System for Indian Remote Sensing Satellite (IRS) transmits the multispectral imagery from CCD Camera to ground for resources management in various disciplines. This system has the capability to collect the data from three Linear Imaging Self Scanning Sensors (LISS). The LISS I data at 5.2 MBPS is transmitted in S band with BPSK modulation while two LISS-II data at 20.8 MBPS is transmitted in X band, with QPSK, modulation [fig.1]. The Data Handling System basically consists of a base band and R.F System. The Base Band system collects Image data, formats them, introduces different synchronizing codes, inserts house keeping parameters and generates serial PCM data. The R.F System contains a local oscillator; modulator, power amplifier and antenna. The baseband data after interface, drives the modulator and transmits through the respective antenna. This paper gives a detailed description of the X band Data Handling System only.

**2. Image Data:** The design of the IRS cameras is based on the concept of push-broom scanning using LISS. Each Camera has 2048 element linear CCD array operating in four

spectral bands. The linear detector arrays are oriented perpendicular to ground track across a scene while the satellite motion provides the coverage in the direction of the scan. The electronics sampling of the detector on the cross track dimensions provides the orthogonal scan component of the image. In addition to the 2048 photosites, the array has another 34 cells generating a few white and dark signal levels intercepted with isolation cells. These standard cells data is not transmitted, but these locations in the format are used for transmitting synchronizing codes and the auxilliary data required to process the image data. The image data is encoded into 7 bit codes.

## 3. Salient features:

### 3.1 Baseband System:

**a.** 127 bit frame synchronizing code; The image data generates continuous 2048 useful pixels data and 34 insignificant pixels data which correspond to 8328 data words resulting in 58296 bits in a frame. A frame synchronizing code of 127 bit length is chosen for this format.

**b.** Camera identification code; One word in the format is alloted for camera identification code to distinguish one of the 3 cameras in IRS Satellite.

**c.** Auxillary Data format; Image data analysis requires satellite health parameters like attitude, position, etc. of the satellite. Four words in the format are allotted for the house keeping [HK] DATA format. Two words, contain the HK data while the other two words contain the word number corresponding to the HK data.

**d.** Timer Data; Twenty four words of the format are allotted to timer. The resolution is 1ms. The data accumulates upto 24 bits.

**e.** Minor Frame Sync [MNFS] code; The format length is 58296 bits and any bit slippage occuring at any length of the format loses the format synchronization there-by causing data loss. To reduce the data loss, minor frame sync codes are inserted at regular intervals in the format. There are about 72 minor frames in the format each having 117 words. There is a Telecommand to bypass the MNFS code from the format. The details of the format is shown in figure 2.

**f.** Differential encoding: There are two PCM streams from baseband which modulate the QPSK modulator for X band transmission. In order to avoid the 4-phase ambiguity in the carrier recovery circuit of QPSK Demodulator a differential encoding with a specific algorithm is used before modulation.

$$An = E1n\ E2n\ An-1 + \overline{E1n}\ E2n\ \overline{Bn-1} + \overline{E1n}\ \overline{E2n}\ \overline{An-1} + E1n\ \overline{E2n}\ Bn-1$$

$$Bn = E1n\ E2n\ Bn-1 + \overline{E1n}\ E2n\ An-1 + \overline{E1n}\ \overline{E2n}\ \overline{Bn-1} + E1n\ \overline{E2n}\ \overline{An-1}$$

**g.** Randomization: Continuous zeros or ones in the PCM pulse stream will cause the NRZ (L) spectrum to have some DC component. To avoid this, the entire PCM data stream except frame Sync Code and Minor Frame Sync Code is randomized using a known PN sequence. This provides additional flexibility for evaluating the link inorbit by carrying out the BER measurement with camera data switched OFF.

### 3.2 RF System :

**a:** Redundancy is provided for the basic crystal oscillator. Through a ground command any one of the two crystal oscillators can be selected.

**b:** QPSK Modulation is used for the two Camera data.

**c:** Cross coupling is provided between TWTAS and the remaining R.F.link.

**d:** Microstrip line configuration used for X band frequency multiplier.

**e**: A Unique temperature compensation is provided for maintaining TWTA input level constant over the temperature range.

**f.** Link margin is greater than 6db.

## 4. SYSTEM SPECIFICATIONS

### 4.1 Base Band System:

| | | |
|---|---|---|
| Bit rate | : | 20.8 MBPS |
| Clock stability | : | 10 ppm. |
| Word length | : | 7 bits/word |
| No. of pixels/frame | : | 2048 useful pixels<br>34 blank pixels |
| Output code | : | RNRZ(L) |
| Frame Sync Code | : | 127 bit PN Code |
| Minor Frame Sync (MNFS) Code | : | 0101110 |
| KNFS Code Repetetion Rate | : | Once in 117 words |

| | | |
|---|---|---|
| Modulation Scheme | : | PCM/QPSK in X Band |
| Power Dissipation | : | 11.5 Watts |

### 4.2 RF System:

| | | |
|---|---|---|
| RF Power Output | : | 43dBM |
| Onboard losses (max.) | : | 3dB |
| Frequency | : | 8316MHz |
| Frequency stability over operating temperature | : | ±1PPM |
| Harmonics | : | -50 dBC |
| AM/PM Conversion | : | 4°/dB |
| Power consumption | : | 74 Watts |
| **QPSK Modulator:** | | |
| Static phase unbalance | : | 6° |
| Amplitude unbalance | : | 0.5 dB |
| Antenna type | : | Circular wave guide with septum Polarizer,beam shaping element and deflector. |
| Antenna gain at ± 62° | : | 7dB (RCP) |
| Return loss | : | 20 dB |
| VSWR | : | <1.2 |
| Length | : | 235mm x 72 |
| Weight | : | 1 Kg. |

## 5. System Description

### 5.1. Base band:

The block diagram of the system is shown fig.3. The 20 MHz crystal oscillator generates all required control pulses through the programmer. The Data Handling System accepts the parallel outputs of the image data in 4 bands and band multiplexes them. This data amounts to 57,344 bits generated continuously. In Minor Frame Sync (MNFS) bypass mode this data is directly fed to ‘Signal Mixing’ logic. In ‘MNFS Select’ mode the image data is fed to the formatter through a memory. For the first minor frame, image data goes to the formatter without any delay. For 2nd minor frame the incoming image data is delayed by one word to accomodate the MNFS code. Subsequently each minor frame data is delayed progressively by one word to accomodate the MNFS codes which occur every 117 words. Depending on the mode selection specified in one of the words in DHS format, image data is fed to the ‘Signal Mix’ with or without MNFS code. There is one word in the format which indicates whether image data is in data mode or calibration mode. As the system will be switched on only when the satellite is visible over the Data

Reception station, the timer data from House keeping telemetry system, which is 'ON' continuously is stored in a shift register and shifted out into the proper location of the DHS format. Complete house keeping telemetry data is transmitted in four words of the Data Handling Format. House keeping telemetry has 8 bits/word,128 words/frame and 8 frames/master frame. Thus there are 1024 words in the master frame. Each HK data word occupies 2 words in DHS format and the corresponding channel identification is provided in the other 2 words. 127 bit maximum length PN sequence is the frame synchronizing code and this is generated using shift registers. This is mixed with all the above data in 'signal mixing' logic. A 1023 bit maximum length PN sequence is generated using shift registers. The entire PCM data except frame sync code and MNFS code is randomized using this sequence. This final output represented as E1n corresponds to Camera 1. There is an identical system generating output E2n corresponding to camera 2. This E1n and E2n are passed through Differential Encoder. The Differential Encoder output is fed to the driver. This driver generates the voltage and current levels required for the interface of the modulator.

### 5.2 RF System:

The block diagram of the RF system is shown in fig.4. The carrier is derived from a crystal oscillator at 277.2MHz. This is a temperature compensated oven controlled crystal oscillator providng a stability in excess of $1x10^{-6}$ over the operating temperature. Two crystal oscillators are coupled through a hybrid coupler and any one is powered which drives the system. The LO is generated by proper frequency multiplication and amplification of the basic crystal oscillator signal. The Differential Encoder o/ps from the Baseband system modulate I and Q channels of the QPSK Modulator. The modulated signal selected from the main or redundant chain is fed to one of the two TWTAS through a coaxial switch as shown in fig.4. The TWTA amplifies the signal to a level of 20 watts and the output is selected by a latching type coaxial RF switch. A four cavity dual mode filter is used to conserve the spectrum and to limit the harmonics before feeding the amplified signal to X-band antenna. Cross coupling is provided with the help of the transfer switch in the input of TWTAS. The X band link calculation is shown in Appendix I.

### 5.3 Antenna

The X band data transmitting antenna is a shaped beam antenna so as to compensate for the path loss. Such an antenna pattern provides a uniform data level throughout the pass. The antenna consists of a circular waveguide with a septum polarizer (to provide right circular polarization), a beam shaping element and a deflector. The beam shaping element has been shaped to provide maximum gain at $\pm 60^\circ$. Beyond $\pm 60^\circ$ pattern falls off sharply. The shaping element is illuminated by the waveguide which inturn illuminates

another reflector fixed at the waveguide mouth. The position of the shaping element is adjusted to get the required pattern. The radiation pattern of the Antenna developed is shown in fig.5.

## 6. Development and Qualification

The X band Data Handling System is being developed for the first time for Indian spacecraft. The developmental phase involves the fabrication and testing of Design verification model engineering model and flight model. During the phase of design verification model, using the actual ground system, the implementation margin was measured. It is found to be 2.3dB. This margin takes care of carrier stability, AM/PM conversion, phase and amplitude unbalance, Rise time and Assymetry in the data and carrier suppression etc. The qualification and acceptance for the IRS has to undergo the test matrix given in table I. The System has been successfully tested for all levels and the consistent behaviour has been ensured.

## 7. Validation with Ground Station:

The Data Handling System is integrated and evaluated with Data Reception station by measuring Bit Error rate (BER) for various signal strengths. The Video Image data is switched Off, resulting in the repetition of randomizing pattern, which is transmitted continuously. After carrier reception and Demodulation the data is subjected to Frame Synchronization and Decommutation. The Decommutated data is recorded in High Density Tape Recorder (HDTR). The tape is played back on a computer system using a specially developed software ‘BER CAL’. The data is compared bit by bit and the BER values are obtained for various conditions of data. The results are tabulated in table II.

## 8. Conclusion

The performance of the complete DHS during all environmental tests is meeting the required specifications. The link performance also is satisfactory. With the experience gained on the performance of the system during the various stages of its testing, the designers are confident that it will perform very well in orbit during the expected life of 3 years after the launch of IRS.

## Acknowledgement

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**Table-I**

| Description | Engineering Model | Flight Model |
|---|---|---|
| 1. Hot and cold | +55°C to -20°C | +55°C to -15°C |
| 2. Thermovac test | +55°C to -15°C at $10^{-5}$ Torrr | +55°C to -10°C at $10^{-5}$ Torr |
| 3. Vibration Test | 20 to 2000Hz. Random and sine wave in X,Y and Z axes. | 20 to 2000Hz Random only in X,Y and Z axes |
| 4. EMI test | as per MIL-461B levels | as per MIL-461B levels |

**Table-II**

| S1.No | Data Description | | No.of Lines checked | No.of bits checked in millions | Bit error Rate |
|---|---|---|---|---|---|
| | Pattern | MNFS code | | | |
| 1. | All ones | select | 2515 | 141 | $4.312 \times 10^{-6}$ |
| 2. | All zeros | select | 2396 | 137.6 | $7.75 \times 10^{-7}$ |
| 3. | All ones | Deselect | 1797 | 103.6 | $5.65 \times 10^{-6}$ |
| 4. | All zeros | Deselect | 599 | 34.7 | $1.9 \times 10^{-6}$ |

## APPENDIX-1

## Link Calculation

| | | |
|---|---|---|
| Transmitter Frequency | : | 8316 MHz |
| Transmitter Power | : | 13 dbw |
| EIRP | : | 18 dbw |
| Max Range for 5° elevation | : | 3003KM |
| Path loss | : | -180.5db |
| G/T of Data Reception Station | : | 30.2db/°K |
| Received CNDR | : | 94.3 db Hz |
| Eb/No. available | : | 21.1db |
| Implimentation Margin | : | 2.5db (Verified) |
| Margin available | : | 7.8db |

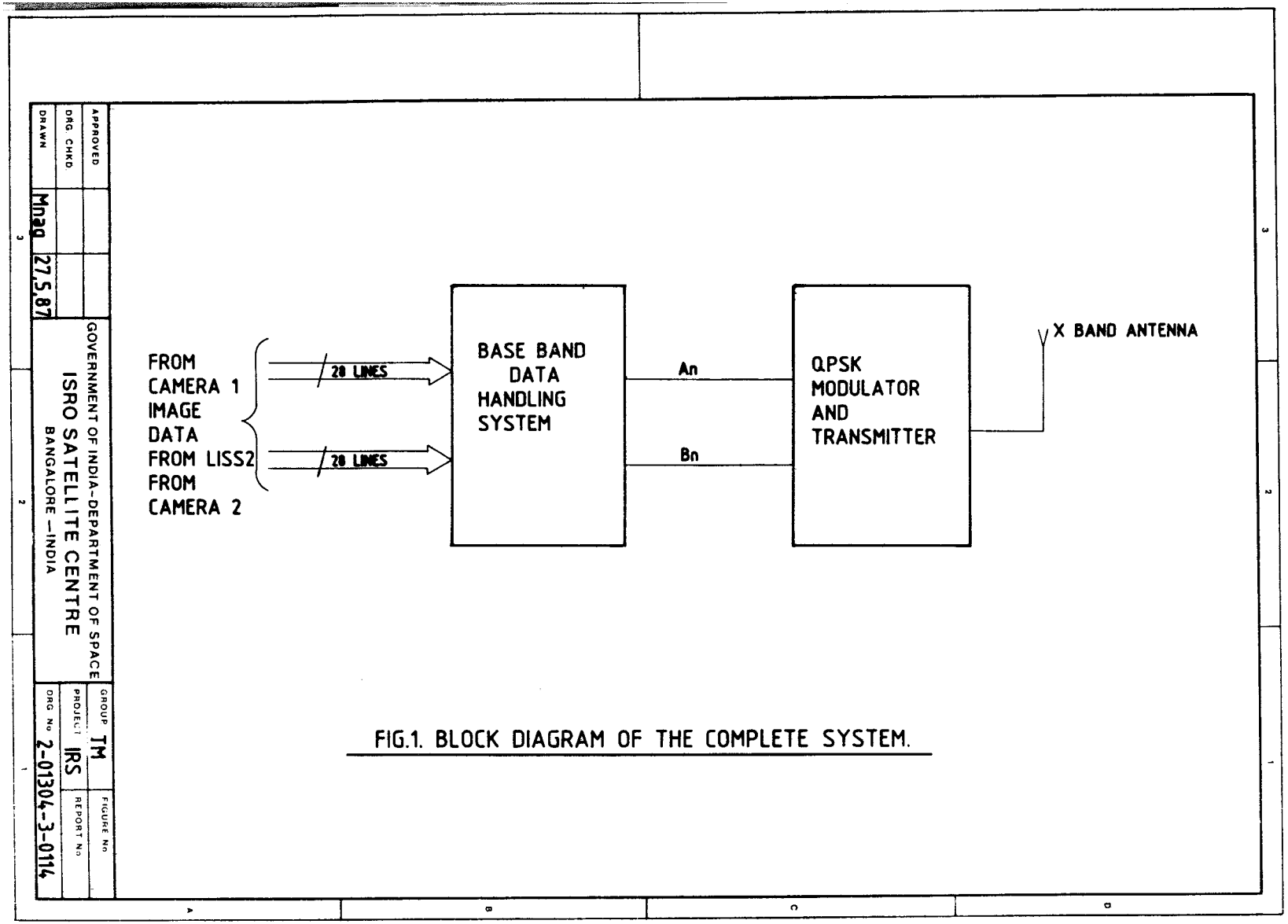


FIG.1. BLOCK DIAGRAM OF THE COMPLETE SYSTEM.

| DRAWN | DRG CHKD | APPROVED |
|---|---|---|
| Mnag 27.5.87 | | |

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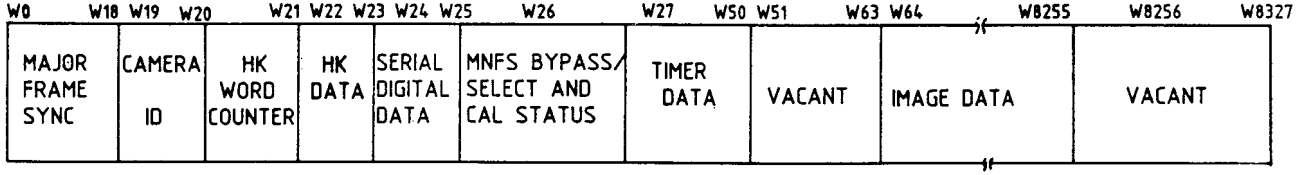
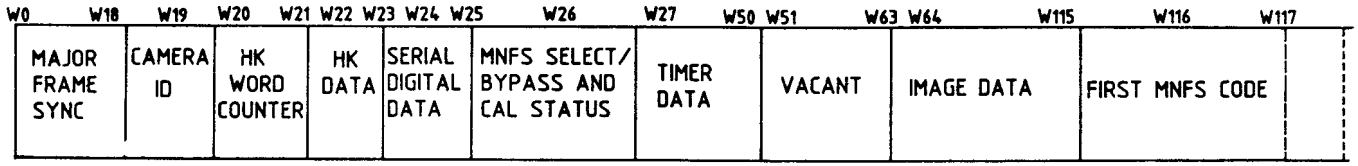
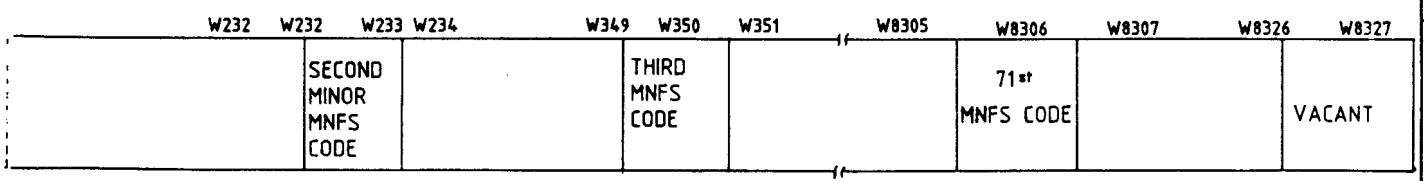
| DRG No | PROJECT | GROUP |
|---|---|---|
| 2-013-04-3-0115 | IRS | TM |
| | REPORT No | FIGURE No |




DATA HANDLING FORMAT (MNFS BYPASS MODE)




DATA HANDLING FORMAT (MNFS SELECT MODE)

W-REPRESENTS =WORD

EACH WORD = 7BITS

FIG.2. DATA HANDLING FORMAT

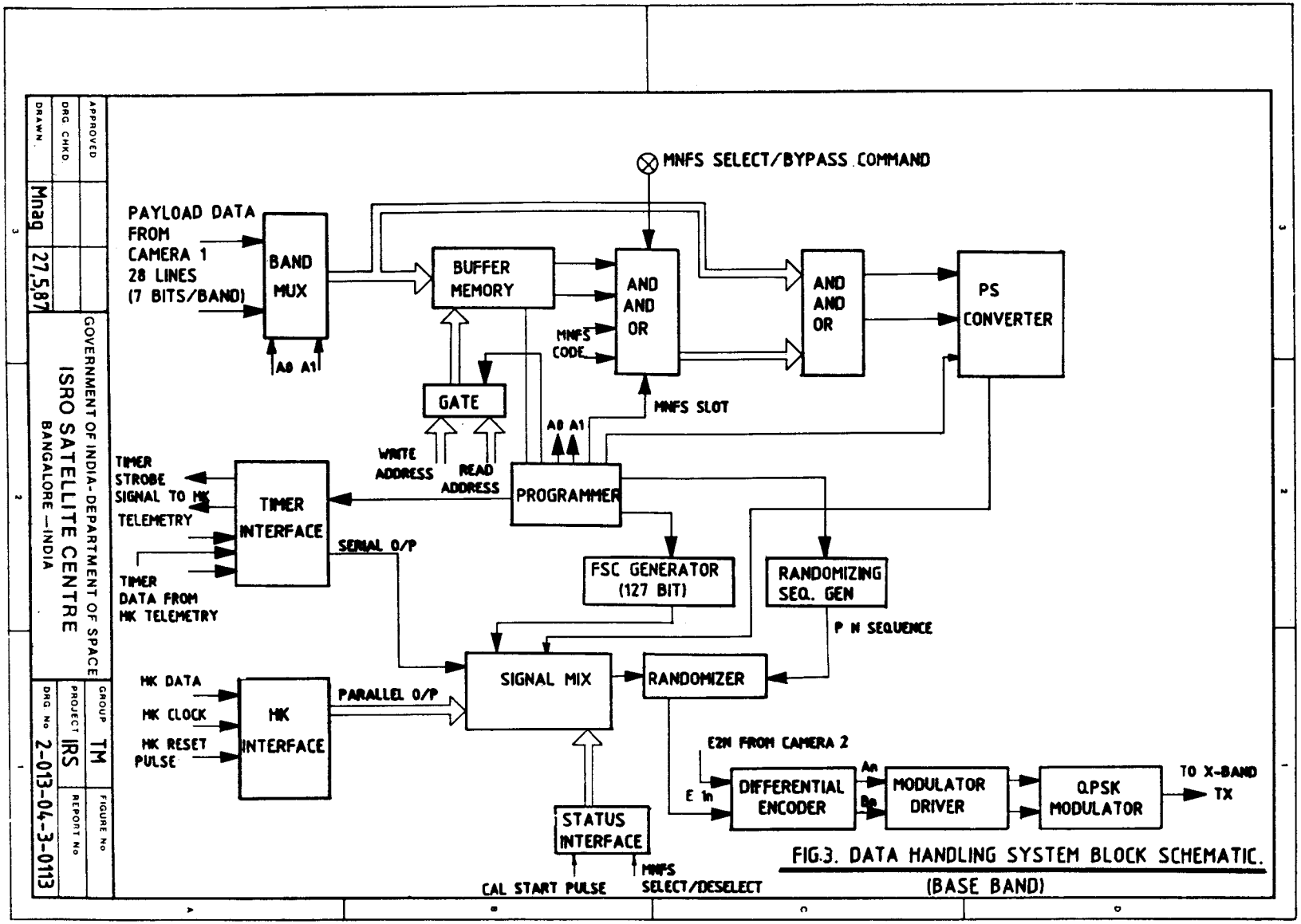



FIG.3. DATA HANDLING SYSTEM BLOCK SCHEMATIC.
(BASE BAND)

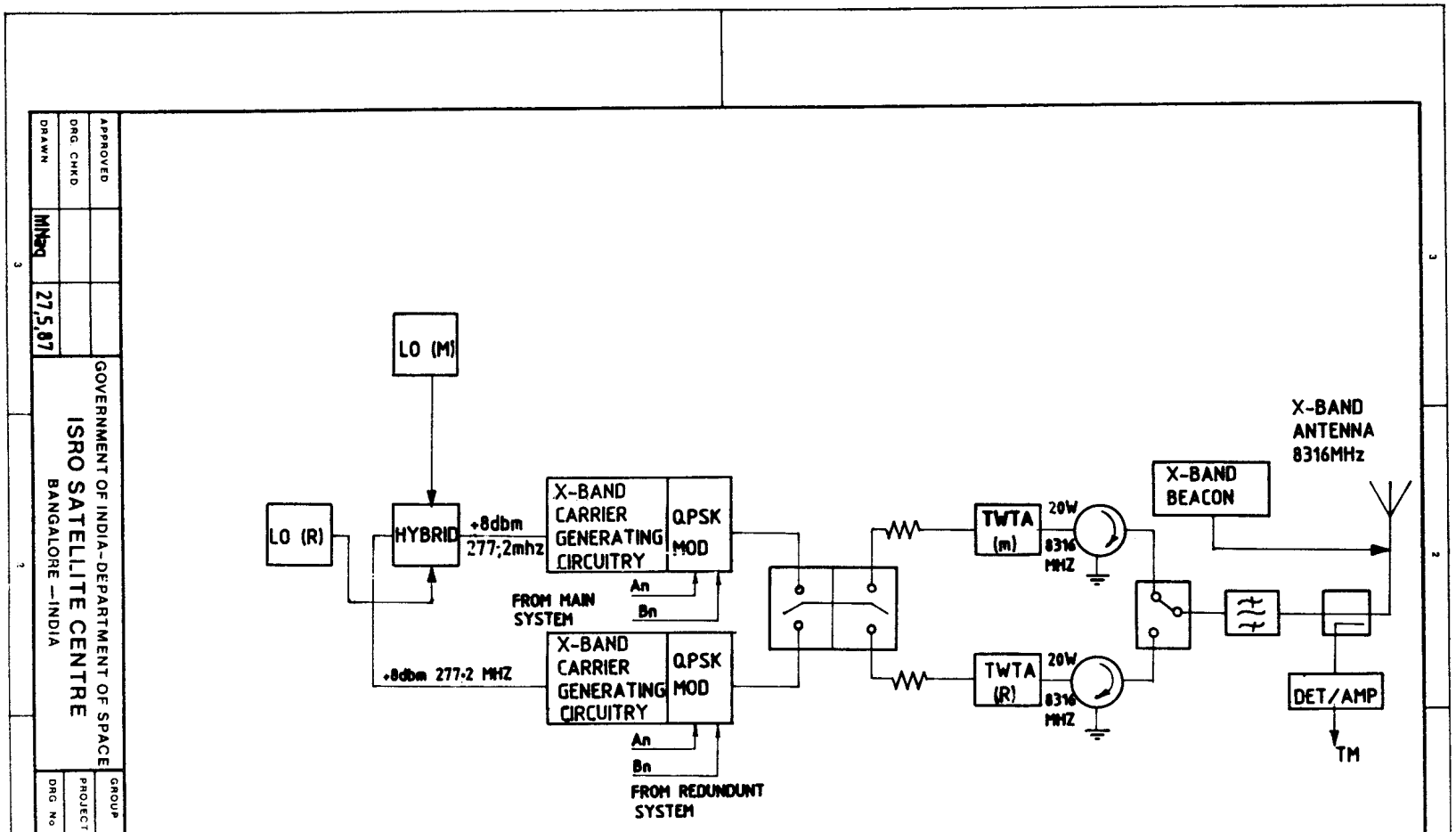



FIG.4. BLOCK DIAGRAM OF DATA HANDLING SYSTEM (RF)

| | | |
|---|---|---|
| DRAWN | MNag | 27.5.87 |
| DRG. CHKD | | |
| APPROVED | | |

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| | | |
|---|---|---|
| DRG No 2-013-04-3-0116 | PROJECT IRS | GROUP T M |
| | REPORT No | FIGURE No |

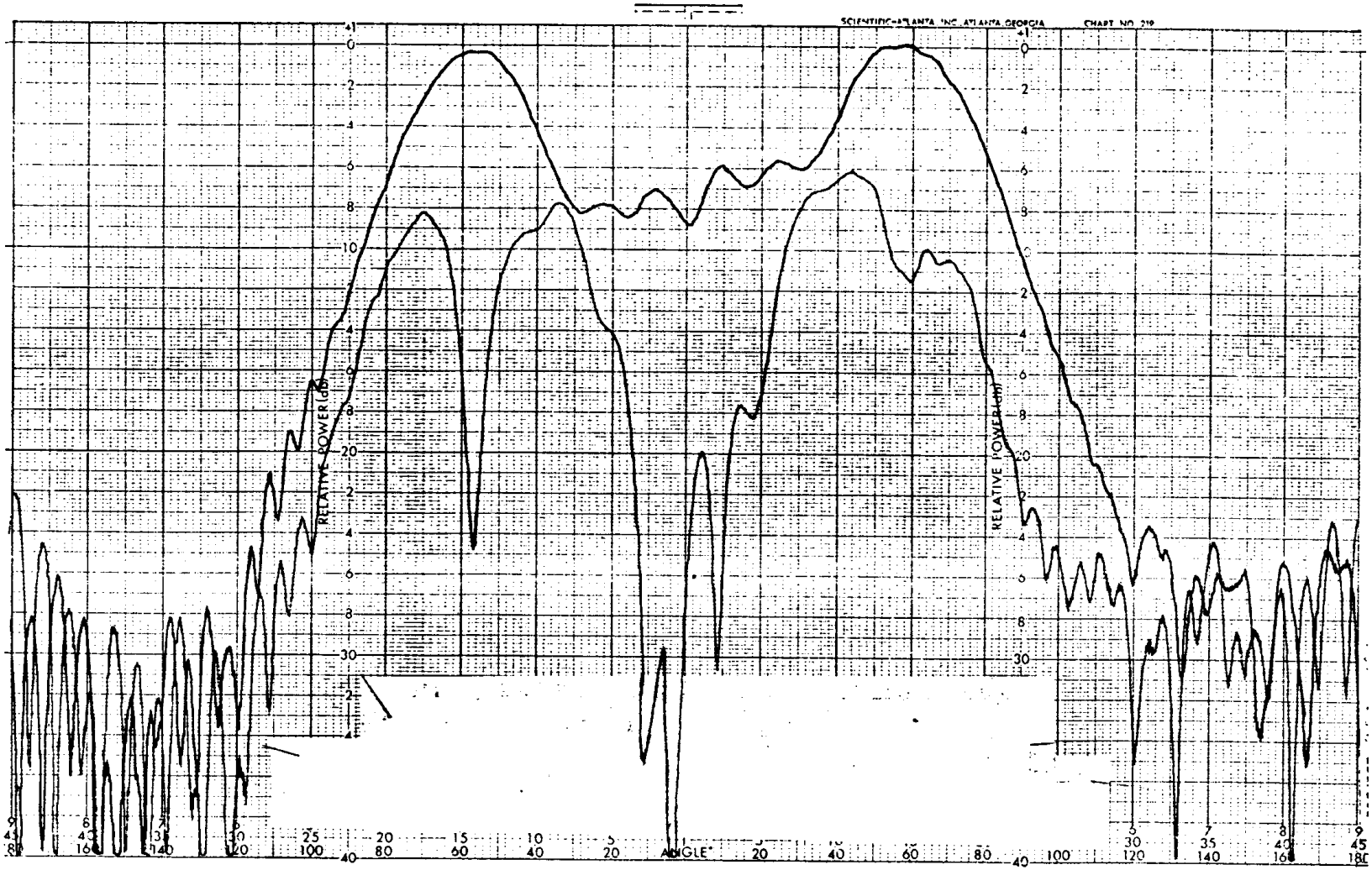


**FIG 5 RADIATION PATTERN OF THE XBAND ANTENNA**