HELICOPTER BORNE TELEMETRY DATA ACQUISITION SYSTEM FOR DOWN RANGE APPLICATIONS

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ABSTRACT

The terminal phase telemetry data acquisition has always been a challenging task especially for long and medium range test launches. The task becomes more complicated if the article under test describes a very low altitude cruise terminal phase trajectory. Generally, for long and medium range missions test fired into sea the terminal phase data is acquired by deploying instrumented ships in the vicinity of impact point but beyond the safety corridor. But for long range missions with low altitude cruise terminal phase trajectory and wide safety corridor this conventional approach will not work out because of limitation of LOS from the ship platforms. Hence, for such applications an air borne telemetry receiving system is also to be added to the down range instrumentation network. This paper describes a typical and cost effective air borne system realized utilizing the Commercial Off The Shelf (COTS) products and technology. This paper also addresses as to how the signal scattering problems are tackled in the design implementation.

Key words

Terminal Phase, Cruise Trajectory, Line Of Sight (LOS), Safety Corridor, Signal Scattering, Down Range, Impact Point, COTS

1 Introduction

During the evaluation of medium and long range missions, health parameters of sub-systems and Navigational data need to be acquired and recorded through telemetry. The instruments are to be deployed for adequate coverage during launch, mid-course and terminal phases of flight path. The tracking and telemetry systems deployed at the launch site will be able to cater for data reception requirements of launch and mid-course phases of flight path. The maximum distance of signal reception is limited by the line of sight conditions. Hence, the instruments located near the launch site will not be able to receive telemetry signals during terminal phase of flight path. To receive telemetry information in final phase of trajectory ship-borne measurement stations are deployed on both sides of expected impact point. Considering the fact that the instruments are deployed to evaluate a weapon system under development and keeping in view the safety of the ships and personnel safety zone of approximately ±30 km away from the impact point is chosen. Stationed at 30km away from the impact point, the ship borne instruments will be able to receive telemetry data only up to 60 meter height above sea level because of limitation of LOS due to earth curvature. For validation of missions cruising at very low altitudes of approximately 5 to 10 m over a range of about 40 to 50 Km the conventional approach of ship-borne Down Range Instrumentation will not be effective. Hence, for solving the problems of reception of telemetry signals at low heights helicopter borne measurement station is developed to ensure required Line Of Sight.

2 Analysis of the requirement specifications

As a Pre-requisite to freeze the configuration design, the requirements with reference to terminal phase telemetry coverage, communication with the Mission Control Center and the Current position display to pilot are analyzed.

2.1 Terminal phase coverage requirements

The mission describes the terminal phase trajectory at an altitude of about 10 meter from sea level over a range of about 40 Km. Based on active guidance philosophy and other aerodynamic considerations the safety corridor during the terminal phase is fixed as +/- 25Km with respect to the nominal path. Hence, the airborne receiving system should have capability to cover the entire zone of 40 km x 50 Km.

2.2 Telemetry requirements

The mission health parameters, Navigation data and guidance performance parameters are transmitted on a single RF carrier. The maximum radiation lobes are perpendicular to the flight path and the signals are linearly polarized. To ensure the secrecy of data certain critical parameters are encrypted using specific algorithms. Hence, the telemetry data acquisition system should be incorporated with real time decryption of selected parameters and decoding of telemetry messages to extract the data required for performance monitoring in real time. Since, the terminal phase data is most important, reception was planned on two independent chains. Stripped telemetry parameters for real time display at mission control center were transmitted, from both telemetry chains.

2.3 Telemetry antenna receiving requirements:

Figure-1 indicates as to how the Horizontal and Vertical Beam widths were calculated. Since, the transmitting antenna is linearly polarized the receiving antenna should be circularly polarized. More importantly each antenna should be planar because of mounting limitations on board helicopter. The LNA needs to be interfaced on the same Antenna plate. Antenna should have enough link margin to cater for minimum reception requirements.

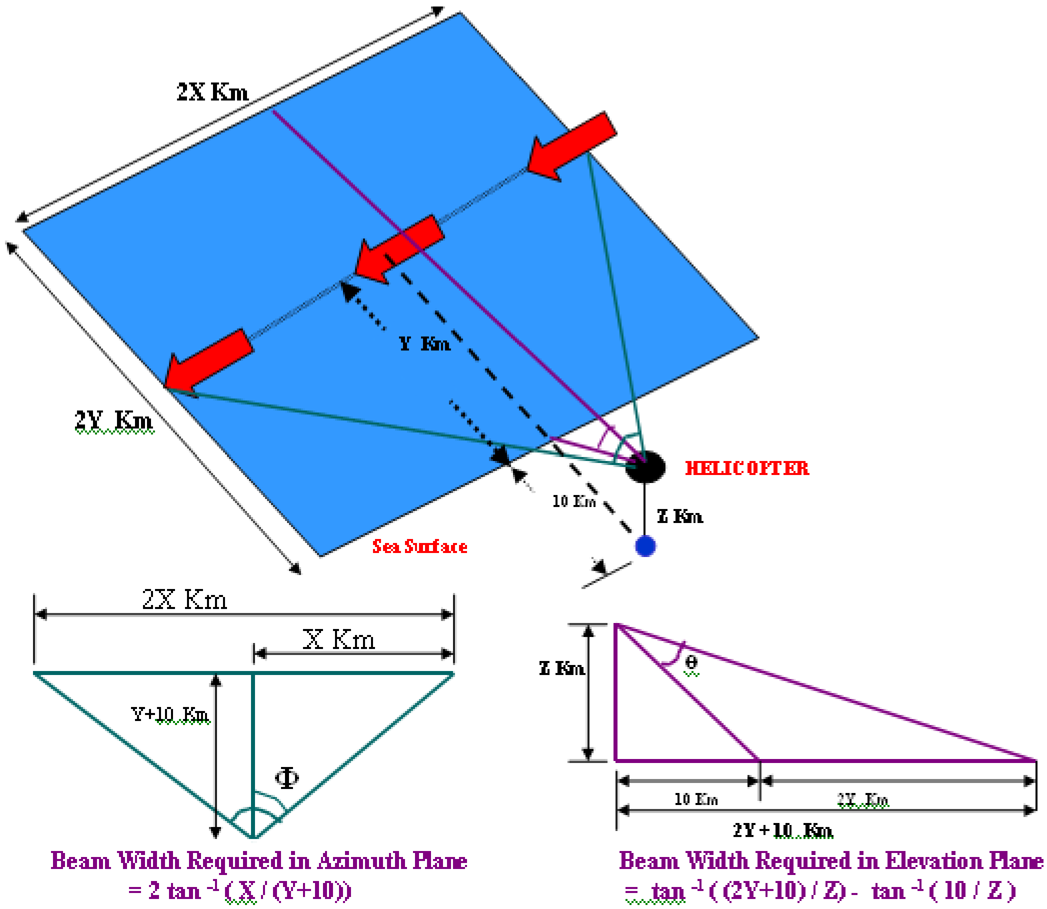


Fig.1 : Terminal phase coverage requirements

2.4 GPS display and position fixing requirements

Since, fixed beam antennae are planned for telemetry reception, the helicopter positioning accuracy during real time launch influences the accuracy of reception. To ensure this important requirement it is proposed to provide the GPS based display to pilot showing simultaneously the expected path to travel and the helicopter current location in distinguishable colors.

2.5 Requirements for data communication in real-time:

Since the helicopter will have to be air borne at least two hours before scheduled mission, the aircraft needs to be in continuous touch with the Mission Control Center to know the current mission sequence and to plan the positioning of aircraft for safety reasons. In addition, to have a real time appreciation of the mission in flight, the stripped telemetry parameters need to be transmitted to the Mission Control Center from the airborne system. Data need to be transmitted on secured communication links. Hence, air-borne secured data communication link is developed and used.

2.6 **Selection of aircraft and finalization of mounting requirements:**

Two options were studied for mounting the airborne system. The first option is Sea King Helicopter and the second option is a fighter aircraft. Helicopter option has been chosen because of limited coverage requirements. The locations for telemetry, communication, GPS antennae and the equipment racks inside the helicopter were finalized keeping in view the helicopter safety criterion.

3.0 **Configuration details:**

Keeping in view the various requirements of the proposed air borne telemetry receiving system, sub systems are configured and realized accordingly. The overall configuration of the system is as shown in Figure-2.

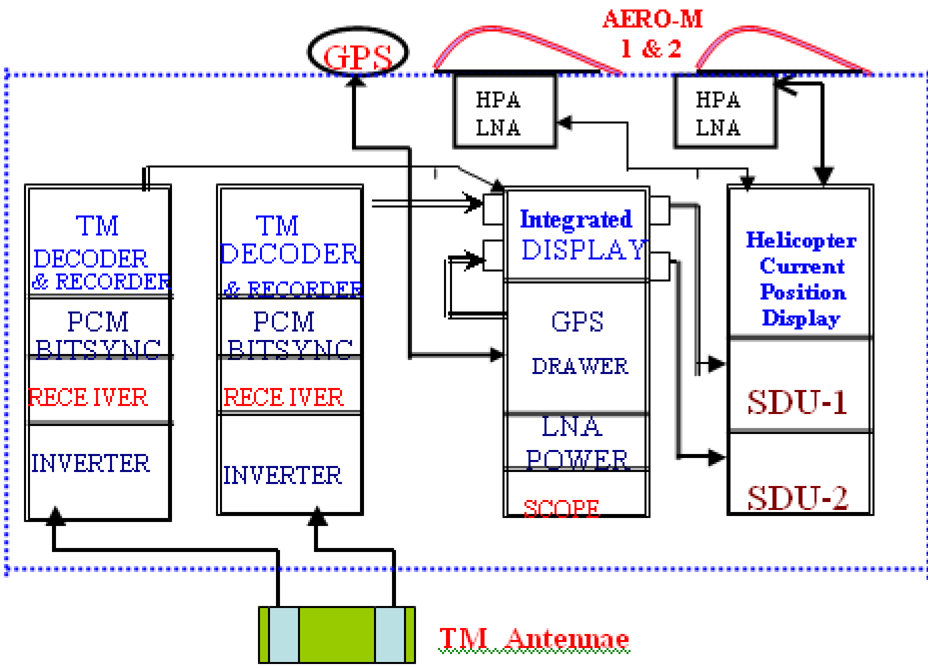


Fig.2 : Airborne System Configuration

3.1 **Telemetry Sub-system:** The configuration of each of the telemetry chains is shown in Figure-3.

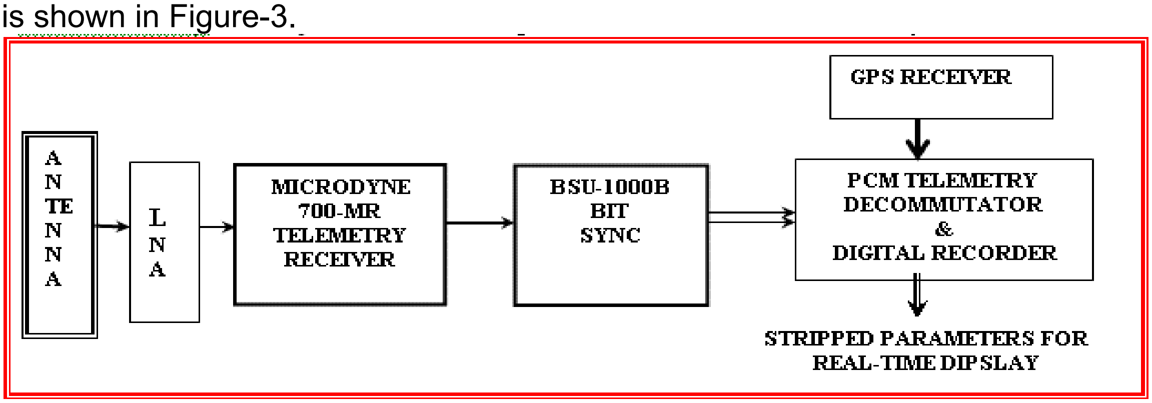


Fig.3 : Configuration of Telemetry Chain

3.1.1: **Broad features of Telemetry sub-system**: The broad performance features of the telemetry subsystem are :

- Reception On two parallel chains for redundancy.
- Time stamping of PCM telemetry frames with IRIG time.
- Real time decryption & decoding of telemetry messages.
- Recording of total telemetry data.
- Transmission of selected parameters.

3.2: Telemetry receiving antennae: Keeping in view the limitations of mounting space available on-board the helicopter and the requirements of asymmetrical beam widths in horizontal and vertical planes, it has been decided to go for patch antenna. Further keeping in view the higher gain requirements and lesser beam width in elevation plane it has been decided to go for ¼ linear array patch antenna. The specifications are given in Table 1.

- Beam width (3db) in Azimuth Plane = 85°
- Beam width (3db) in Elevation Plane= 20°
- Gain of the antenna = 12 dBi
- Polarization = Right Hand Circular & Left Hand Circular

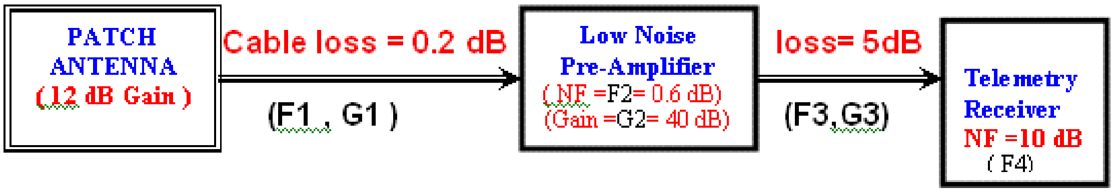
Table 1

3.3 **Low Noise Amplifiers**: The Low Noise Amplifiers were integrated along with the antenna plate to achieve the best performance. The broad specifications of LNA are given in Table 2:

- Frequency Band of Operation= S-Band
- Gain = 35 dB
- Noise figure = 0.6dB
- Gain flatness = ± 0.5dB
- O/p at 1dB compression point = +35dBm.
- Power Supply = +15V DC

Table 2

3.4 **Link Margin Calculations:** The system noise temperature has been calculated for the given configuration of the link as shown below. The corresponding link margin calculations are shown in Table 3.



F1 = 0.2 dB F2 = 0.6 dB F3=5dB F4= 10 dB
G1= - 0.2 dB G2 = 40 dB G3= -10 dB

Equivalent Noise Figure = F1 + (F2-1)/G1 + (F3-1)/G1*G2 + (F4-1)/G1*G2*G3
= 1.0478 + 0.1549 + 0.0000226 + 0.0029
= 1.2026

Equivalent Noise Temperature = 61.68^0 K
System Noise Temperature = $T_A + T_{Equu.}$
➢ = 100 + 86.7 = 161.7^0 K (Say 200^0 K)

Transmitting power (P_T)	= 10 Watt	=	10 dB
Transmit Antenna Gain (G_T)	=		-4 dB
Cable Loss (Two-way divider)	=		-3 dB
Polarization loss	=		-3 dB
Receiving Antenna Gain (G_R)	=		12 dB
System Noise Temperature (T_S)	=	200^0 K =	23 dB
Receiver Band width (B_{IF})	=	3.3 MHz=	65.2 dB
S/N required for good PCM Lock	=		12 dB
Calculated path loss	= $P_T + G_T + G_R$ - Misc.Loss - K - T_S - B_{IF} - S/N = 140.4 dB		
Range coverage capability corresponding to calculated path loss =109 Km			

Table 3

3.5 **DATA ACQUISITION SYSTEM:** Indigenously developed Bit synchronizers & Data acquisition systems are utilized. Software for the real time decryption & decoding of MIL-STD-1553 messages and transmission of selected parameters to MCC is developed and validated in house.

3.6 **GPS system**: A GPS configuration based an existing DGPS drawer was adopted to meet the proposed GPS requirements (See Figure-4)

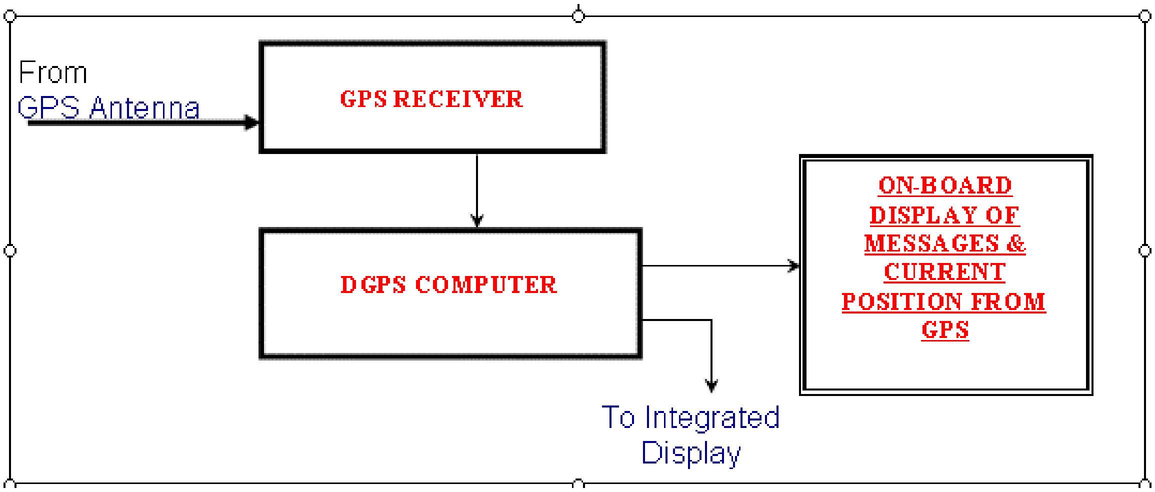


Fig.4: GPS System Configuration

3.6.1 **Broad features of the GPS system:** The following are the broad features of the GPS system.

- Reception of GPS data and plotting of the current helicopter position, heading and speed in real time for local monitoring.
- Transmission of current helicopter GPS location to Mission Control Center via secured communication data link.

3.7 **Air-Mobile communication system:** AERO-M INMARSAT terminals manufactured by M/s Thrane & Thrane, Denmark are utilized to establish global air mobile connectivity between Air-borne System and Mission Control Centre. The data through-put of AERO-M (2.4 Kbps) is sufficient to transmit up to 60 bytes of multiplexed data at 5 frames/sec required for the mission. The relevant software modules required for multiplexing the data & messages to a form suitable for the encryption are developed in house.

3.7.1 **AERO-M communication system**:The AERO-M INMARSAT terminal provides global connectivity with the aid of internal navigation reference system. The antenna and the outdoor unit are specifically designed to meet the aircraft applications. In this application, it is required to establish bi-directional 2-4 Kbps data link between helicopter & Mission Control Center, with the aid of this link. The configuration of the link on air borne plat form is given in Figure 5.

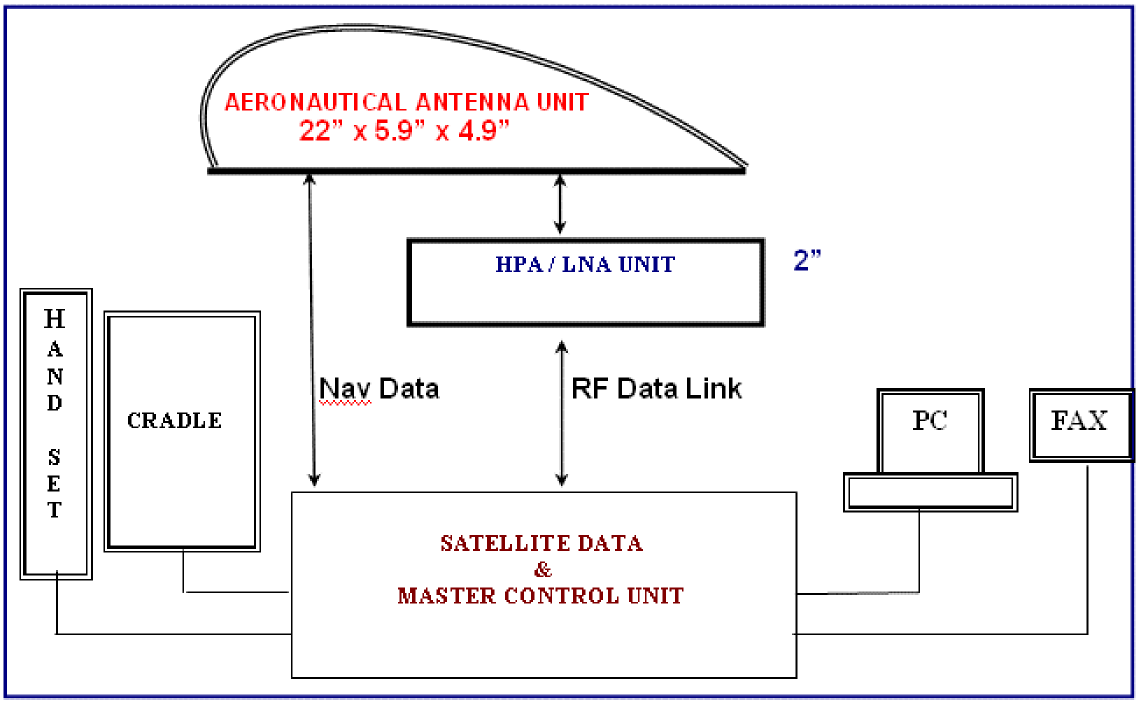


Fig.5: Configuration of the air mobile communication link

3.7.2 **Broad Features of the air mobile communication link**: The following are the broad features of the air mobile communication link.

- Single Channel System that provides transfer & telephone calls, fax print and data/e-mail/ services.
- Stand alone operation with built-in internal navigation reference system.
- RS-232 compatible interface for data transmission @ 2.4 K
- Interface availability for 2 phones, RS-485 four wire handset and other two wire 600Ω, G.743 DTMF phone and one fax interface.
- Altitude up to 16.8 Km for HPA/LNA & 4.6 Km for SDU.

3.7.3**: Realization Scheme of air mobile communication link:** The entire system as shown in figure-6 is realized. The software development & testing were conducted using the existing MINI-M terminals. The entire system study, integration, commissioning, link establishment and Application Software Validation were carried out in a short time before installing the system On-board the helicopter.

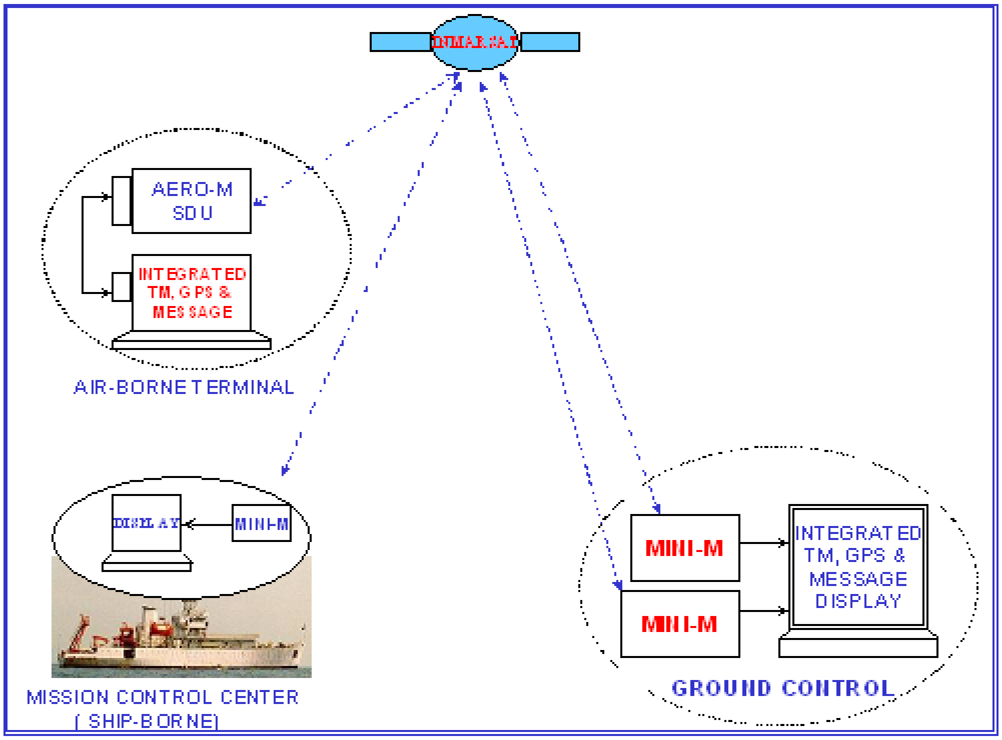


Fig.6: Realization scheme of air mobile communication link

3.8: Integrated Display: To meet all the requirements of telemetry data display at Mission Control Center, to present the ground trace of helicopter at MCC and transmission/reception of mission related secure messages, an integrated display has been designed and implemented. The scheme of the display configuration on board helicopter is shown in Figure-7and the corresponding configuration at Mission control center is shown in Figure-8.

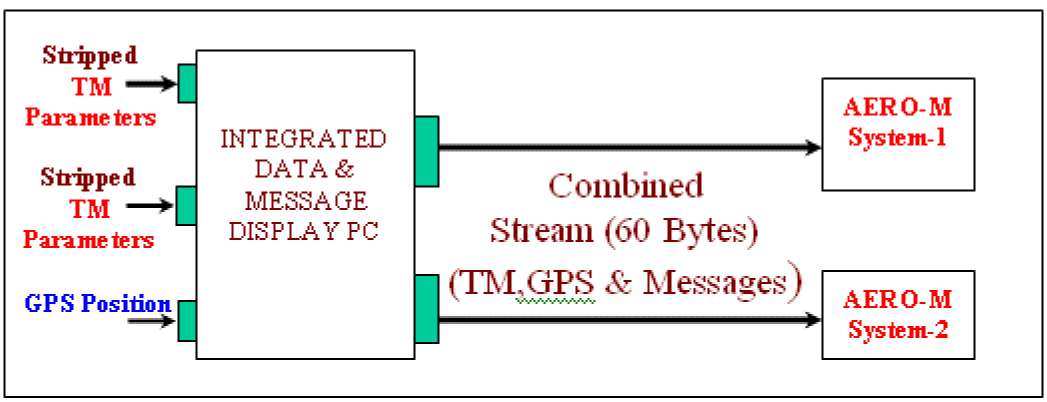


Fig.7 : Integrated display configuration on-board helicopter

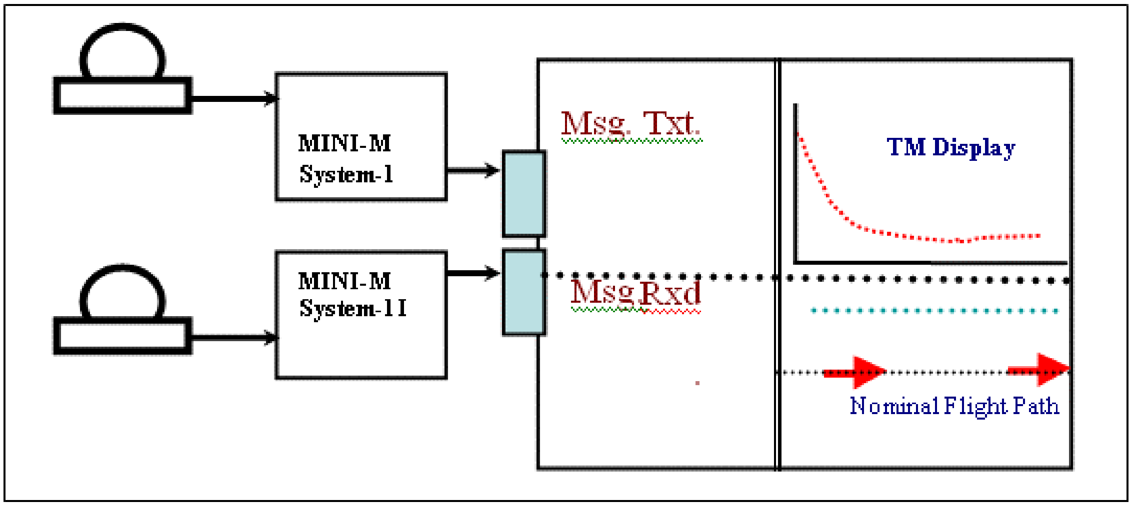
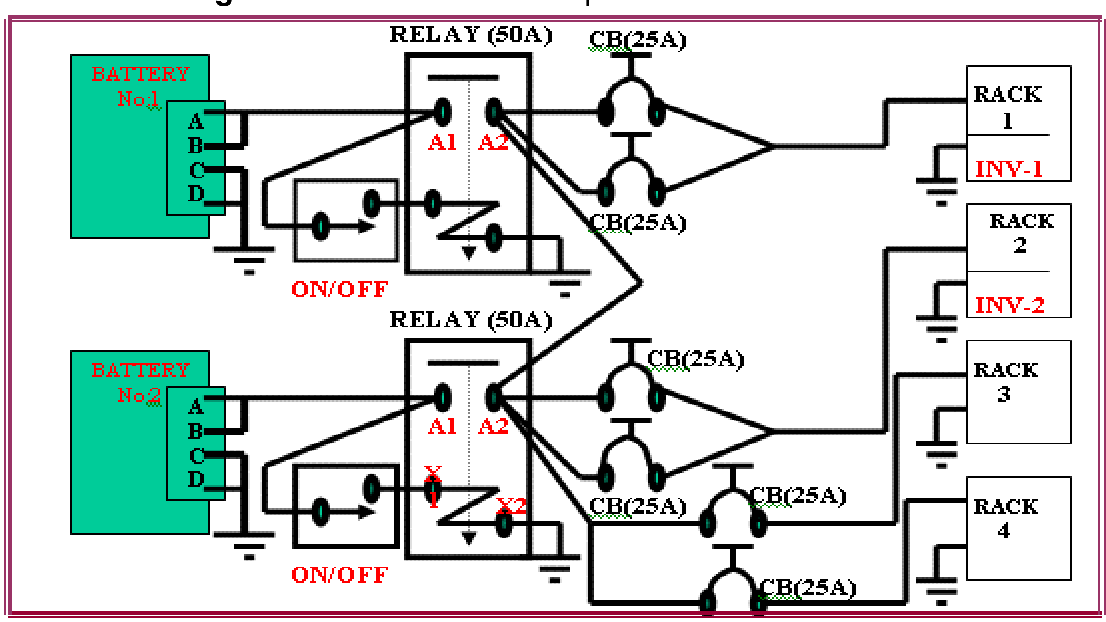


Fig.8: Integrated display configuration at mission control centre

3.8 **Helicopter modifications**: Designed and fabricated the interface panels for mounting various antennae outside the helicopter and equipment racks inside the helicopter. Each of the instrumentation rack has been fitted with spring loaded shock absorbers to isolate the sensitive electronic equipment from the vibrations and shocks experienced during take-off and flight.

3.9 **Electrical load analysis & realization scheme**: Total power consumption requirement is worked out to be 3.0 KVA. For supplying A/C power indigenously developed 2KVA rugged inverters are used. The inverters are powered using high-energy batteries. The batteries were designed to provide backup for 03 hours time. The scheme of Electrical distribution on board helicopter is shown in Figure-9.

Fig.9 : Scheme of electrical power distribution



4.0 **System validation :** The system validation was carried out in two stages. During stage-I validation, the helicopter was flown at 40Km distance from test tower in a fixed azimuth line at an altitude of 2.5Km for about 80Km distance. A telemetry transmitting system with exactly same format and power output was located on the top of test tower which is at an elevation of approximately 12m. This deployment is very close to the mission requirement except that during actual mission the article will fly while helicopter is relatively stationary. Further, during the validation trails, all the communication links to Mission Control Center were activated. Stage-II test configuration is similar to stage-I except for a difference that the test was carried out in the sea environment.

05. **Effect of Water Surface on Radio Wave Propagation**: Since, the system has to operate under sea environmental conditions, the effect of sea water on radio wave propagation is studied and all possible measures are taken to reduce the effects of sea reflections on the system performance.

5.1: **Analysis of sea water reflection**: Effect of multi-path propagation is equivalent to generation of multiplication factor MF. MF is equal to the ratio of the actual Electrical Field Intensity existing at the reception point to the maximum electrical field Intensity that would have existed for an ideal case of free space radio wave propagation. Effect of multi-path propagation becomes more predominant, when the receiving antenna is located above the RF Signal source which travelling along the water surface. In this case the radiation reaches the receiver both from the forward wave (direct) and the reflected wave from the water surface. Hence, the Field Intensity at the receiving point is the effect of summing up of two waves taking into consideration their amplitude and phase.

Expression for MF on interference of direct and indirect waves can be presented in the following form:

$$MF = | f(V_1) + \rho \cdot f(V_2) \cdot e^{-j\alpha} | \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

Where V_1 is the angle in the vertical plane, determining the direction of forward wave, and V_2 determines the direction of reflected wave. F(V) = Co-efficient of antenna pattern, which is equal to the field strength in the direction of “V” to the field strength in the direction of maximum intensity. Angle “α” is equal to the sum of ‘Angle of reflection factor (Φ)’ and difference of phases (β), determined by difference of path lengths (δ) between direct and reflected waves.

$$\text{Alpha } (\alpha) = (\Phi) + (2\pi / \lambda)\,\beta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If the object of radio emission is located at a distance of ‘R’, which is much more than the height of the object of radiation above water surface h1, then the angles V_1 & V_2 may be considered equal.

The formula (1) can be simplified as:

MF = f(V) . Sqrt (1 + ρ^2 + 2. ρ. Cos (α)) ……….. (3)

Where ‘ρ’ = Factor of reflection from the surface.

‘ρ’ = r. ρ_0 , where r = roughness factor.
ρ_0 = Factor of reflection from smooth water surface.
V = Slide Angle.

Geometrical relations during multi-path propagation is given in Figure-10.

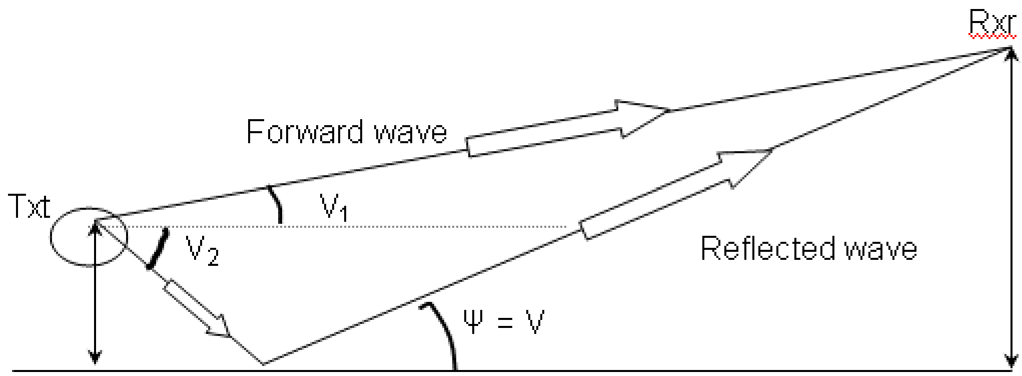


Fig.10: Geometrical relations during multipath

Extremeness conform to the values of V, for which ‘(Φ) + (2 π / λ) δ’ Serves as either maximum or as minimum values. If ρ=1 and f(V)=1 assuming smooth completely reflecting surface and isotropic antenna, then the values of ‘MF’ will alter between 0 and 2.

Based on the analysis of the data available in the literature ‘ minimum value of factor of reflection from water surface for wavelength of 13 cm is assured at a slide angle V=5 Deg. Accordingly the height of helicopter flying and the Patch Antenna tilt angles are finalized.

06. **Results & conclusions**: The system realization has been accomplished using the Commercially Available Systems as far as possible to keep the cost and development cycle time the minimum. Protective measures have been taken in the rack design with respect to their mounting so as to reduce the transfer effects of shock and vibration to the individual equipment. The system was deployed in a series of mission experiments and had proven to be very successful. The fixed beam antenna coverage can be up graded with phased array based auto track antenna system so as to cover longer distances.

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