SYNCHRONOUS-SATELLITE SERVICE FOR AERONAUTICAL FLIGHT TESTING - AN INDIAN MODEL

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ABSTRACT

One of the fastest methods of flight testing prototype aircraft and other aerospace vehicles is to use real-time tele-links. This method, has cutshort flight development cost, time and effort considerably. However, there are certain shortcomings in this methodology, such as, limited range, multipath effects, capability to test only one aircraft at a time, using auto-track systems, limiting the scene of activity to one centre etc. Opening other flight test centre in the country would mean duplication. With the daunting prospect of flight testing supersonic fighter aircraft in the 90's, it becomes necessary to think of alternatives. This presentation describes a synchronous satellite system concept, as a suitable alternative for the Indian environment. It is concluded that in the Indian context, an operational system based on this concept is absolutely feasible and that a follow-up system would be a Domestic MILSAT communication network that apart from serving the flight test needs, meets the service requirements of other military aeronautical agencies in India.

INTRODUCTION

Present day real-time telemetry system help reduce flight development cost and time frame effectively. However, they are still dogged by problems such as (i) limited range (ii) multipath interference etc. Remedial measures to overcome these shortcomings include the installation of auto-track antennas, deployment of low-altitude relay aircraft etc. These methods are however expensive in the long run and difficult to maintain. Also, an auto-track system can serve only one flying aircraft and, low altitude flying relay aircraft, while extending the line-of-sight range is not a permanent solution. Moreover, all the above mentioned improvements to present day real-time tele-links confine the scenario of flight test activity to one geographical location.

With the rapid development taking place in the field of aircraft design, flight control systems, materials technology and aircraft propulsion, futuristic aircraft are expected to be highly maneuverable, fly at supersonic speeds and have 2 large radius of operation. To combat these daunting requirements and still effectively conduct real-time flight tests, the flight test engineer has to conceptualise and evolve alternate systems that are more permanent and universal in nature.

Lebow, Jordan and Drouilet [1] conducted in the mid-60's a series of communication experiments to study the feasibility of data transmission between satellites and aircraft. The study utilised the LES-3, LES-5 and LES-6 experimental satellites. The PLACE experiments [2] [3] conducted with the ATS-F satellite also helped to throw light on the application of satellite links to mobile Platforms. The experiments utilised the P-Band. Meier, Woodford and Dutcher [4] [5] had proposed a North Atlantic Domestic Satellite communication system for air-traffic control for the 80's. However so far, no complete operational system has been proposed for aeronautical flight test applications. The reasons may be varied such as: (i) utility (2) cost (3) necessity and (4) operational viability. With the dwindling cost of satellite technology the above restrictions seem to be fast disappearing and hence, this proposition. The reasons for seeking such a solution are not too far:

(i) With the tremendous developments taking place in satellite technology, ground terminals are becoming cheaper vis-a-vis the cost of the more sophisticated satellite. The "technology inversion" thus taking place, has overcome the limitations of on-board power, weight, volume etc.

(ii) Communication between far flung areas and widely dispersed vehicles in space and ground, mobile or stationary, has become a reality with the deployment of the synchronous satellite.

The satellite system concept takes into account the above favourable factors. A phase-wise programme-plan towards achieving this objective is indicated. The growth potential areas are touched upon. In conclusion, it is emphasised that a model communication network of this nature, catering initially the flight test needs, and serving other military aeronautical agencies of India in future, is entirely feasible to implement.

SYSTEM CONCEPT

The Flight Instrumentation Satellite (FINSAT) system geometry is presented in Fig.1.0. As the system is global in nature the following assumptions are made:

(i) All flying aircraft prototype or otherwise, undergoing tests are coherent with the Master Flight Test Centre (MFTC).

(ii) Multiple aircrafts of different categories are being flight tested simultaneously, and

(iii) The origins of flights are not necessarily confined to one geographical region or airfield.

Prior to the commencement of a test programme it is essential to ensure that all the test aircraft are coherent with the MFTC. To achieve this objective, the MFTC generates a pilot carrier signal at 6-GHz. This signal is picked up by the FINSAT Antenna/Receiver, amplified, translated through a transponder and converted to a signal at 4 GHz. It is then re-transmitted to all aircraft. The individual aircraft transponder/Receiver phaselock to this 4-GHz signal. All the aircraft are now coherent with the ground station. Information from the various aircraft is then transmitted to the FINSAT. The FINSAT receives this spectrum of information and after pre-amplification is downconverted to the base band. This baseband signal then phase-modulates a carrier which is coherent to the received C-band signals. It is then upconverted to the C-band and is processed through the FINSAT transmitter. The MFTC receives the carrier and recovers the subcarrier information for further processing. The entire exercise requires multiple access capability that provides for the simultaneous operation of a satellite system at C-Band.

. For achieving this the FINSAT receiver needs a linearity that prevents the multiple carriers from the various aircraft, produce significant intermodulation components; when the multiple carriers arrive they are translated to the base band frequencies and then phase-modulated on to respective carrier signal. This involves the use of selectable baseband filters. The phase-modulation index is also kept at 1 radian, independent of the number of carriers, and this requires adequate AGC in the transponder. The process is schematically explained in the Fig. 2.0.

SYSTEM SELECTION

A detailed description of the main segments of the FINSAT operational system is beyond the scope of the presentation for the following reasons:

(1) Selection of the ultimate system can be effected only after working out the finer details of the technical and financial aspects of the operational plan and

(2) The state of the art in Avionics and Satellite technology prevalent in India at that point of time.

It will also depend on:

(a) Type of data to be transmitted and its bandwidth.

(b) The duty cycle of the users accessing of the operational system.

SYSTEM IMPLEMENTATION

The entire satellite system plan is expected to be implemented in two phase:

PHASE I

A detailed study would be made of the technical requirements and an action plan drawn up for conducting communication experiments. The experiments would be based on the FDMA technique and would operate in the 6/4 GHzband. A simple block schematic of the aircraft and ground segments envisaged for this purpose is given at Fig.3.0.

The satellite segment will in general follow the schematic as shown in Fig.2.0. Experiments conducted will include (a) Tests to prove the coherency of the aircraft with the MFTC (b) The maximum rates of data transmission achieved vis-a-vis the bit errors logged (c) The mutual interference noticed between the A/c-SAT, SAT-A/c,MFTC-SAT and SAT-MFTC Links. The experiments will be conducted with aircraft instrumented and launched from at least three different widely dispersed bases. These tests will be primarily used by us to optimise on the aircraft antenna system as also to gain firsthand experience in the operation of satellite links. A sample link design is given at Table 1.

A study of the sample link design indicates the following:

(1) The present Ground telemetry antenna of 2.5m dia can be used with modification in the feed design to operate at 6.0 GHz.

(2) The aircraft antenna should consist of top and bottom ones, filted on the nose or any other converient locations and having an hemispherical pattern, so as to given an effective gain of 10db

(3) The satellite antenna can be a 2.5m dia umbralla type dish which has to be deployed after launch in the synchronous orbit.

The experiment has a frequency plan as explained below:

(1) A single Transponder of 36 MHz bandwidth will be utilised.

(2) The operational link will work in the 6/4 GHz frequency band.

(3) The Transponder will be shared by 14 pre-assigned carriers, each having a maximum of 2 .5 MHz bandwidth.

Table II indicates the spot carrier frequency allocations for the various aircraft.

PHASE II.

This would be the actual operational system of FINSAT which would later be in hanced as a Military Satellite (MILSAT) system. This system would adopt the latest PCM-PSK-TDMA techniques and would probably operate in the 12/13 GHz band. Data transmitted would include aircraft parameters, voice and image. Rapid advances being made in the areas of up and microelectronics technologies, microwave/antenna systems and in Digital/signal processing would be utilised. A representative schematic of the system (aircraft and ground) incorporating these high technology principles is given below as Fig.4.0.

SYSTEM ADVANTAGES

A operational system based on this principle has certain distinct advantages. Some of these are:-

(1) LOS Range is no longer a limiting factor.

(2) Multipath problem between aircraft and ground station are almost totally eliminated.

(3) The system caters for the testing of more than one aircraft at a time, launched from the same base or different bases.

GROWTH POTENTIAL

As stressed earlier, the system has growth potential in catering to the other military aeronautical services of the Indian government such as (i) Military aircraft traffic control (ii) Navigation (iii) Search and Rescue mission etc. A system of this nature can also serve the flight test needs of a consortium of countries which are engaged in Advanced aircraft development programme, as for eg. in Western Europe.

CONCLUSIONS

An operational system based on satellite technology has been proposed as an alternative to present day real-time tele-links. As all aerospace activity in India is confined to the government sector, an operational system based on this principle is absolutely feasible. It would also lead to better co-ordination between the various aerospace agencies.

ACKNOWLEDGEMENTS

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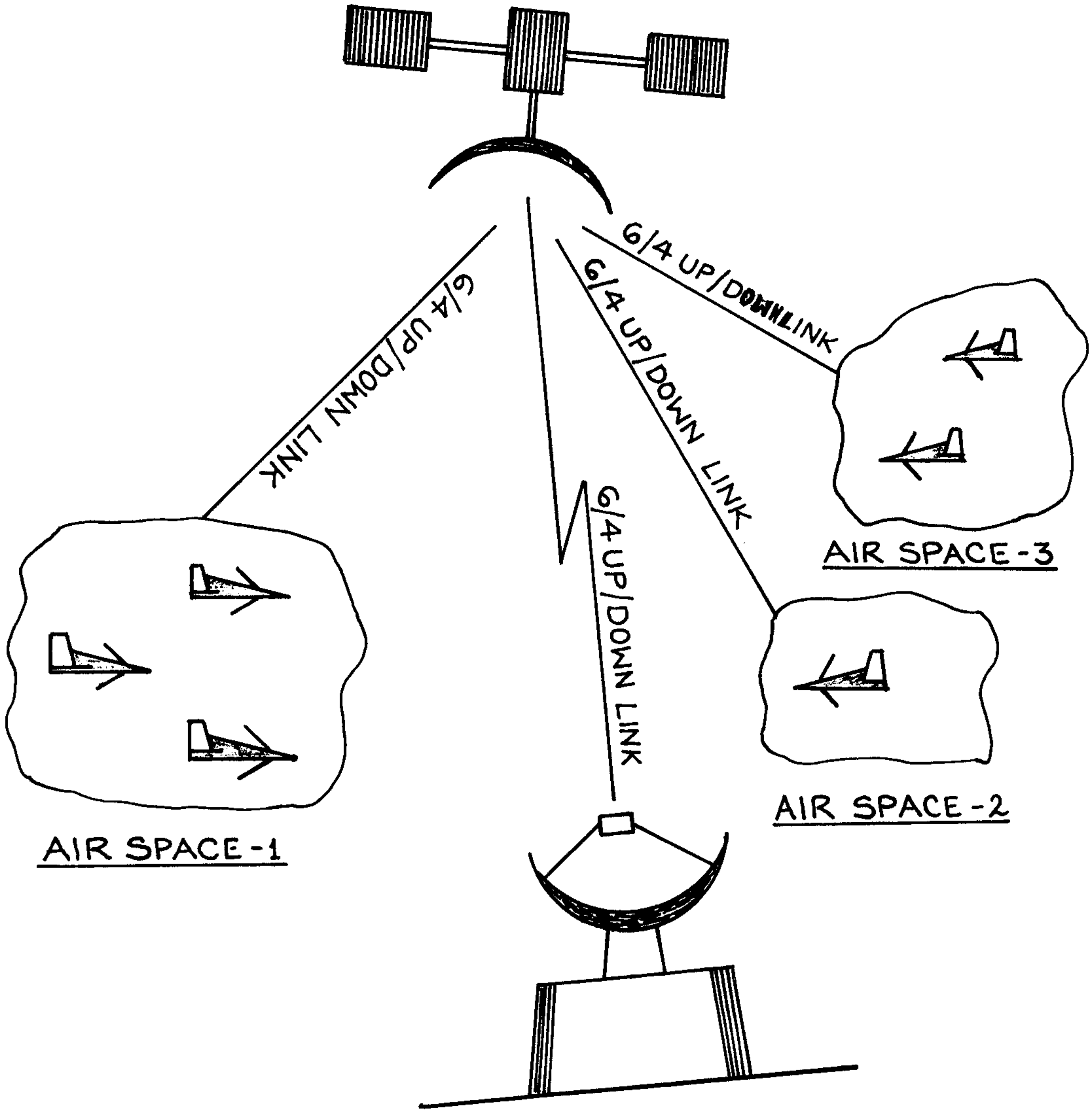

FIG.1.0. FINSAT SYSTEM GEOMETRY

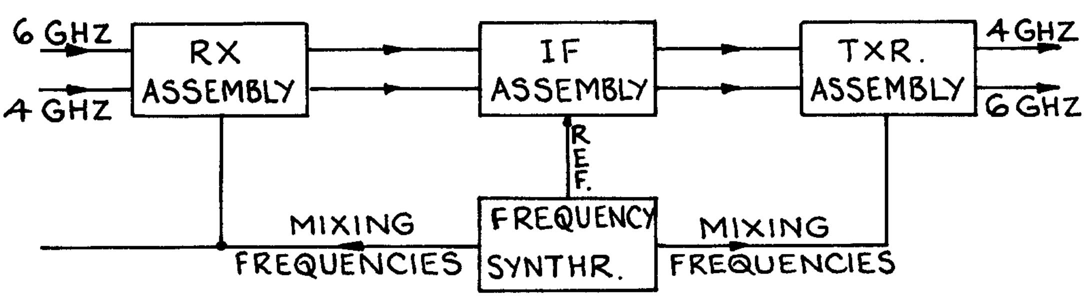

FIG.2.0. FINSAT TRANSPONDER

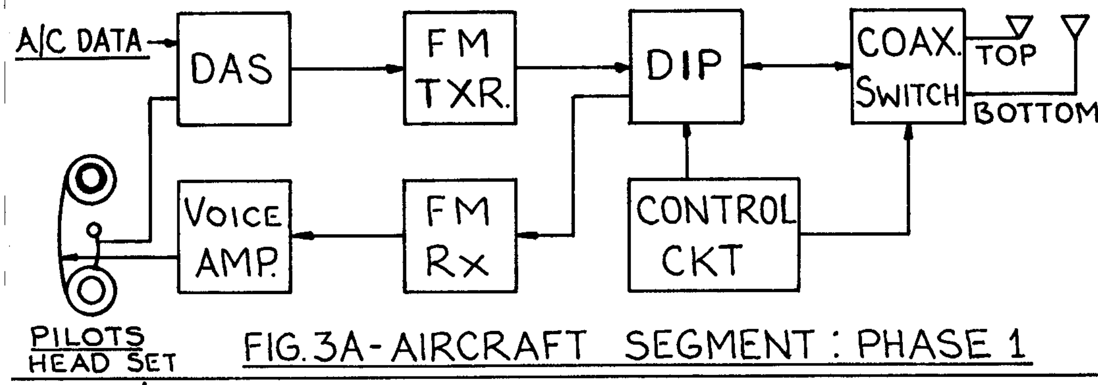

FIG. 3A - AIRCRAFT SEGMENT : PHASE 1

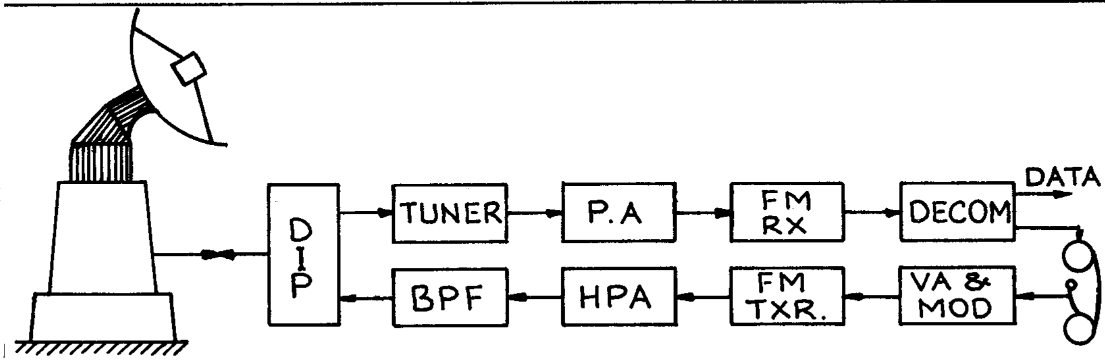

FIG. 3B - GROUND SEGMENT : PHASE 1

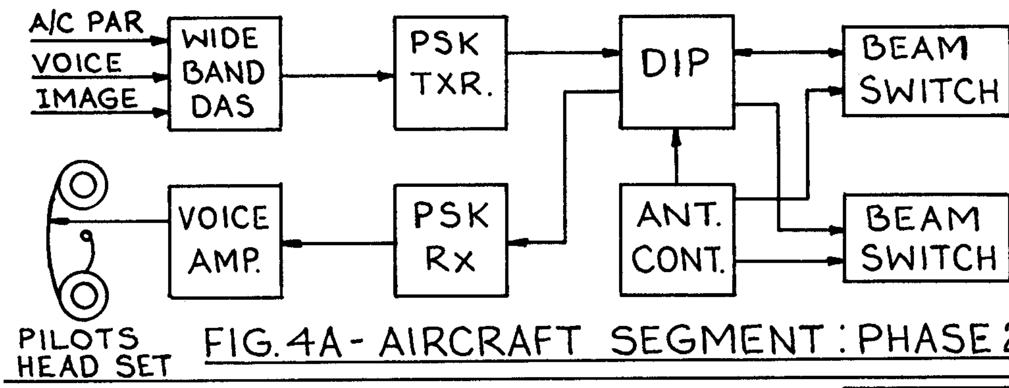

FIG. 4A - AIRCRAFT SEGMENT : PHASE 2

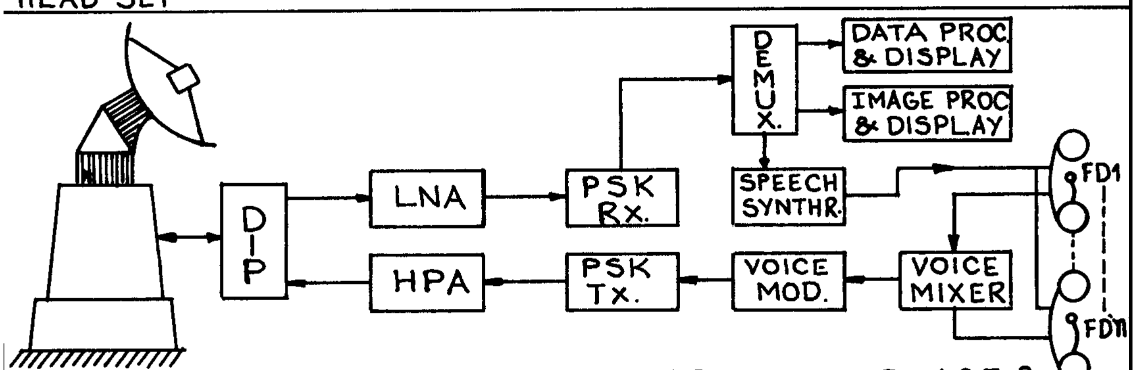

FIG. 4B - GROUND SEGMENT : PHASE 2

TABLE I

SL.NO.	LINK COMPONENTS	MFTC/ SAT. (6 GHz)	SAT./ AIRCRAFT (4 GHz)	AIRCRAFT/ SAT. (4 GHz)	SAT./ MFTC (6 GHz)
1	TRANSMITTER POWER (dBW)	20.0	20.0	20.0	20.0
2	TRANSMITTING SYSTEM LOSS (dB)	-1.0	-1.0	-1.0	-1.0
3	TRANSMITTING ANTENNA GAIN (dB)	40.0	37.0	10.0	40.0
4	ATMOSPHERIC LOSS (dB)	0.0	0.0	0.0	0.0
5	FREE SPACE LOSS (dB)	-190.0	-185.0	-185.0	-190.0
6	RECEIVING ANTENNA GAIN (dB)	40.0	10.0	37.0	40.0
7	RECEIVING SYSTEM LOSS (dB)	-1.0	-1.0	-1.0	-1.0
8	RECEIVED POWER (dBW)	-92.0	-120.7	-120.0	-92.0
9	NOISE TEMPERATURE (^{o}K)	180.0	360.0	180.0	360.0
10	RECEIVED BANDWIDTH (MHz)	36.0	2.5	36.0	36.0
11	NOISE POWER (dBW)	-140.0	-139.1	-140.0	-127.5
12	RECEIVER SNR (dB)	48.0	18.4	20.0	35.5
13	LOSS IN BAD STORM (dB)	2.0	2.0	2.0	2.0
14	RECEIVED SNR IN BAD STORM (dB)	46.0	16.4	18.0	33.5

TABLE II

6 GHz BAND	4 GHz BAND
5.945	3.720
5.980	3.755
6.015	3.790
6.050	3.825
6.085	3.860
6.120	3.895
6.155	3.930
6.190	3.965
6.225	4.000
6.260	4.035
6.295	4.070
6.330	4.105
6.365	4.140
6.400	4.175