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## MSAT SIGNALLING AND NETWORK MANAGEMENT ARCHITECTURES

PETER GARLAND, Advanced Programs, J. MALCOLM KEELTY,  
Communications Group.

SPAR AEROSPACE LIMITED  
Satellite and Communications Systems Division  
21025 Trans Canada Highway  
Ste. Anne de Bellevue  
Quebec, Canada  
H9X 3R2

### ABSTRACT

Spar Aerospace has been active in the design and definition of Mobile Satellite Systems since the mid 1970's. In work sponsored by the Canadian Department of Communications, various payload configurations have evolved. In addressing the payload configuration, the requirements of the mobile user, the service provider and the satellite operator have always been the most important consideration.

This paper reviews the current Spar 11 beam satellite design, and explores its capabilities to provide flexibility and potential for network growth within the WARC87 allocations.

To enable the full capabilities of the payload to be realized, a large amount of ground based Switching and Network Management infrastructure will be required, when space segment becomes available. Early indications were that a single custom designed Demand Assignment Multiple Access (DAMA) switch should be implemented to provide efficient use of the space segment. As MSAT has evolved into a multiple service concept, supporting many service providers, this architecture should be reviewed. The paper explores some possible signalling and Network Management solutions.

### INTRODUCTION

The possible implementation of a Mobile Satellite Service on the North American continent has been investigated by Government agencies in the USA and Canada since the early '70's. The 1980's have seen the evolution of those investigations into solid business plans for a joint USA/Canada operational system sponsored by private sector organizations (TMI and AMSC). At the same time specialist maritime and geolocation network services have been put into operation by Inmarsat and Geostar. At the 1987 WARC frequency spectrum was allocated for Land Mobile Satellite Service (LMSS), whilst retaining spectrum dedicated to Aeronautical Mobile Satellite Service (AMSS) and Maritime Mobile Satellite Service (MMSS).

These allocations were at L Band, 1530-1559 MHz Mobile Receive and 1626.5 MHz-1660.5MHz Mobile Transmit.

During the time that these various business and regulatory led changes have taken place, the design of the satellite payload has evolved to fit within the new requirements. The current payload requirements are described in (1) and summarized below.

- o Two satellite system providing mutual back up over Canada, Conus USA, Alaska and Mexico.
- o Designed to operate with mobile antennas from 4 dBi up to 15dBi.
- o Provides full area coverage in the four bands allocated at WARC 87, over the complete 29MHz allocation.
- o Flexible bandwidth/power distribution over coverage area.
- o Spacecraft hardware for both the Canadian and US spacecraft should be functionally identical.
- o Ku Band backhaul.

The payload flexibility will allow the operators to support Mobile Telephone Service (MTS), Mobile Radio Service (MRS) and Mobile Data Service (MDS) over the satellites complete coverage area. It will also allow the operators to supply leased bandwidth and power to other service providers e.g. Inmarsat, to enable the extension of specialized services into the MSAT coverage area.

#### PAYLOAD CONFIGURATION

The basic payload configuration provides eleven beam coverage with frequency switched beam selection. The payload is simplified by the exclusion of any L Band to L Band connectivity. This excludes the option of Mobile to Mobile direct connectivity sometimes proposed (2) in preliminary operational requirements. Connectivity in the payload is restricted to L Band to Ku Band Backhaul, Ku Band Backhaul to L Band, with some Ku Band to Ku Band capacity. Figure 1 shows a functional block diagram of the payload.

Separate Rx and Tx antennas are used to support the L band operations. These are nominally 5 meter deployable mesh parabolic antennas. A low level beam forming network is combined with the Hybrid Matrix transponder (3) to produce a very flexible L band power distribution system. Frequency switching into the 11 beams is achieved by the use of a multiple element switched filter matrix. This ensures that the available bandwidth can be routed to any one or a combination of beams.

The routing of the available power is a function of the distribution of bandwidth. Because of the need to support several mobile services, using mobile terminals with differences in antenna gain and elevation to the satellite, power distribution is not tied in a linear fashion to frequency distribution. This has a direct impact on the complexity of Power Management in the Ground Segment as discussed further in this paper.

The bandwidth/power flexibility required in the payload determines the complexity of the Switched Filter Matrix. Three elements of its design determine flexibility.

1. The bandwidth of each filter element - Determines the granularity of the band sections that can be switched.
2. The number of filters - Determines - a) Amount of first use bandwidth available; b) Amount of frequency reuse bandwidth available
3. Number of contacts on the matrix switch - Determines the number of beams into which each band section can be switched.

Figure 2 shows a limited function filter switch matrix, switchable into 5 beams. Here each filter is 150KHz wide, there are six filters in total, and each switch element has two or three contacts. A normal operational matrix will have more filters that range in selected bands across the whole 29 MHz available. Also the 11 beam system will give a greater flexibility in reuse between beams (Figure 3). Due to the direct trade off between operational flexibility and the complexity of the switched filter matrix full consideration of future operational requirements must be made before the design is frozen.

Presently, it is imagined that the Canadian spacecraft and the US spacecraft will contain an identical number and type of filters, with the same switch configuration. This will allow a complete one for one redundancy for each band section, in the event of filter or switch element failure. In terms of complexity Spar has found that a baseline design giving 15 MHz first use bandwidth and 6 MHz reuse bandwidth, in 75-240 KHz switchable bands is feasible with current technology and spacecraft bus support. This will allow service in each of the main WARC 87 bands within each beam. Some exclusions can be made to minimize complexity e.g. exclusion of Maritime coverage within the mid-continent beams.

Due to limitations imposed by passive intermodulation in the antenna feed design, the Power Management facility will need to ensure that no more than 40% of available L-band Power is applied to any one beam.

#### NETWORK MANAGEMENT ISSUES

Original Canadian concepts of MSAT were based around an homogeneous range of mobile services provided under a strict central control. This would have limited the variety of mobile equipments deployed, simplifying the role of the Network Management function. Major factors that must be considered as the program has moved from government support into the private domain are:

1. The pre-emptive implementation and growth of INMARSAT services, particularly the projected Aeronautical Service.
2. The importance to the commercial success of the project of business entrepreneurs to whom a new modulation scheme, access technique or equipment design may be central to their product offering. Rigid standardization in all areas will exclude these enterprises.

3. The development and successful deployment in the field of a large amount of Inmarsat standard technology.

These factors, combined with the obvious need for the basic Ground Infrastructure deployment to be on a schedule commensurate with Space Segment availability, leads to a re-assessment of the architecture of the Network Management System.

Some major issues that can be identified as important in the specification of the Ground Segment infrastructure and have a direct bearing on efficient use of the Space Segment are:-

- a) The methods and degree to which power control can be applied to the forward link carriers.
- b) The amount of partitioning that can be tolerated in the Demand Assignment Switching (DAMA) function.
- c) The method of controlling power, bandwidth, and access to those users that lease capacity.
- d) The connection of the Network Management System into the Spacecraft Telemetry Command & Control (TT&C) system, to allow full use of spacecraft payload flexibility.

a) Power Control on the Forward Link

As described above the flexibility of the 11 beam designed payload comes from the routing of carriers into beams by frequency selection. As the power available at the satellite in the Forward Link is a precious resource, it is important for the operator of the satellite to monitor and control its use. It is also important for a service provider to minimize the per user cost, by limiting power to the level required for acceptable service.

The problem of power control and distribution would be very simple if a constant power/bandwidth ratio was always achieved. However, several factors combine to complicate the power use in the satellite. Table 1 lists these in 3 categories.

Table 1

Fixed - Licensed parameters of Mobile -

Antenna type  
Service type  
Service Quality  
Availability Level

Periodic - Slowly Changing Parameters -

Satellite Elevation  
Position in Beam

Dynamic - Constantly Changing Parameters -

Degree of Shadowing

Fixed parameters are easy to control by type approval of remote terminals.

Periodic parameters can be handled automatically on a continuous basis (Data Service) or on a per call basis (Voice or Switched Data Service). In a spot beam system it is important for a mobile to establish which beam it is in. This can be achieved as in the INMARSAT aeronautical case by scanning outbound signalling channels transmitted in each beam by the master control terminal. The channel with the best BER reading determines the beam assignment, which also determines the mean satellite elevation. The absolute BER reading in the channel can also give an indication of the position within the beam. A more complex algorithm within the mobiles, that compared the BER's from all signalling channels, could determine with greater accuracy the position within a beam and the elevation to the satellite.

Because of short term variations due to shadowing this process would need to be periodically performed when the mobile is not engaged in a call. This information would be stored in the DAMA system data base and would also be used to set up a PSTN or base station originated call. As this information is produced by constant measurement of the level of the signalling channels, it may be possible to compare with an expected standard or to view the pattern of short term variations to determine the shadowing terrain (4). This would require greater sophistication in the firmware of the mobile, but could at least determine whether the mobile was in an extended urban environment or flat treeless terrain. By adjusting the fade margin accordingly, over a large number of mobiles a significant power saving could be made.

#### b) DAMA Partitioning

Early Canadian concepts for MSAT defined a centralized DAMA system with two separate DAMA processors

1. MTS DAMA processor
2. MRS DAMA processor

Two separate processors were recommended due to the different traffic characteristics of MRS calls and MTS calls, the major difference being in call holding times which are an average of 20 seconds for MRS and 3 minutes for MTS (5). Also an MTS call can be efficiently handled in the same way as PSTN calls, in that blocked calls are cleared. In the MRS case the biggest source of call failure may not be in the availability of transmission channels, but in the unavailability of Base Station equipment or personnel. Therefore, a blocked calls cleared procedure may cause unacceptable numbers of retries. It has also been suggested that due to the 20 second typical hold time of an MRS call, a deferred channel assignment algorithm be adopted.

A factor that has now emerged is the need to provide some services with guaranteed priority access. It may be possible to implement a single DAMA system with several layers of priority. However, due to a need for autonomy, some service providers may require to operate with pre-assigned service or their own DAMA system.

The development of specialized DAMA switches as described above involves large high risk development programs. An important consideration must be the need for the traffic management system to be in place when dedicated MSAT space segment becomes available. It will be important in minimizing schedule risk to review operational systems or systems where a large amount of pre-development has already been undertaken. Two candidate systems are the Inmarsat Standard B and Aeronautical Standard. These standards are, however, both designed for MTS service, with non-deferred assignment and blocked calls cleared algorithms. In a non-deferred system an operational channel is assigned to the calling party at the time they go off-hook, prior to the passing of the called party's address digits, and of course before the called party answers the ring. The latter delay may be as much as 10 seconds. This would increase the "call time" of a MRS call to 30 seconds, thus reducing the number of users that can be supported in the network.

Modification of an existing Inmarsat system to satisfy the MRS requirement may require large development and schedule risk. There may be some benefit in considering a two process approach, one for MTS which can be in place very quickly and another for MRS which may require development. This separation does not necessitate a move away from common standards; indeed the signalling protocols may be very similar, allowing identical hardware in the mobiles. The solution may be to provide two autonomous software packages in a common processor. The intention is purely to identify two separate functions to allow a modular approach and reduce interdependence.

c) Control & Monitor of Space Segment Leases

Leasing of Space Segment to service providers can be an important source of revenue to MSAT operators. As always when Space Segment is sold the buyer will purchase a portion of a resource. The resource in this instant is a fraction of the total L Band Power and Bandwidth. In fixed satellite services the basic methods of charging for partial transponder leases are similar; Telesat's charges are based on highest percentage use of either power or bandwidth, and Intelsat leases a section of bandwidth with which comes an allocation of power.

A scheme could be adopted in the MSAT system where a number of 5KHz channels can be leased. With each channel comes an entitlement to an amount of L band downlink power. The lessee can then incorporate schemes such as packet transmission, DAMA, voice activation, and power management to derive the maximum use from his allocation. In the MSAT spot beam environment, due to the granularity of the frequency bands defined by the switch filter matrix, it may be necessary to require a minimum capacity lease in each beam, or to encourage cooperative leasing arrangements.

A challenge for the satellite operator is to ensure the lessee does not exceed his power allocation. In global beam systems this is done by continuous measurement of user carrier levels at a central control & measurement site. In the MSAT spot beam environment, however, duplication of facilities would be required in each beam. It may be more practical to set down rules based on the type of equipment proposed and the type of service, and evaluate if the lessee's service level can be met by his stated allocation requirements. Spot checks can then be performed by mobile measuring stations to check major parameters on a non-continuous basis.

d) Network Management and TT&C Connection

It is most certain that to be economically viable, the MSAT payload will be supported on a standard commercial spacecraft bus system. Indeed to this point, all of the payload designs considered by Spar have been limited to known bus systems. With each of these spacecraft buses comes a standard telemetry system with a set frequency band, modulation scheme and communications protocol. In its support of a standard communications payload the normal load on a TT&C system is quite small; its role is one of supporting the built-in redundancy provisions of the payload, monitoring health, and initiating redundancy switching. The spot beam design for MSAT does not present a large extra requirement on the TT&C system. The Hybrid Switch Matrix will need to be programmed, and will therefore need a number of switch closure commands, proportional to the number of switches in the matrix. The operational environment imagined is one where a TMI or AMSC operator will respond to one of two scenarios by initiating a reconfiguration.

1. A sign that a degraded grade of service is being offered to a customer in one or more areas.
2. A request has been made to improve service or initiate a new service

This reconfiguration will involve providing more bandwidth to a spot beam, either by switching in an unused filter, or by switching a filter over from another beam. The operator will need to be provided with Network Management software with a user friendly interface, allowing the reconfiguration to be edited into the current configuration off-line. When this new configuration is required to be implemented a translation would be performed to convert into TT&C command format.

The procedure described above is manually initiated and infrequently performed. It may however also be feasible to perform automatic reconfigurations, to redirect capacity into different time zones depending on traffic loading patterns. To do this, it would be necessary to generate a number of alternate matrix switch plans activated on a time sequence. This would greatly increase the traffic on the TT&C system, but a processor based satellite bus could be pre-programmed with application software, purposely designed to lower the traffic on the TT&C link.

The above requirement shows that there is in fact a close link between the Space Segment TT&C requirements, and the Ground Segment Network Management requirements. This link further emphasizes the importance in having a coordinated systems approach to the total MSAT infrastructure, including Space Segment, Signalling and Network Management.

## Network Management and Signalling System

The Network Management and Signalling System, to support a cooperative MSAT system having the Space Segment characteristics described in this paper, must be able to support top level Satellite operator functions such as:-

- Bandwidth and Power distribution
- Restriction on Satellite Access
- Monitor and Control of major ground infrastructure elements as well as satellites
- Provide top level links between the two operations' Network Control Stations (NCS)
- Provide channel access control for all Land Mobile Services (MTS, MRS and MDS)
- Provide priority access for Aeronautical Mobile Satellite Service (AMSS)
- Allow the monitor and control of Space Segment lessees

To satisfy all of the technical requirements listed above, a two layer hierarchical approach as shown in Figure 4 could be employed. At the lower layer of this hierarchy a number of front-end processing units would handle the tasks of

- Land Mobile Telephone Service DAMA
- Land Mobile Radio Service DAMA
- Land Mobile Data Service Hub
- Aeronautical Mobile Service DAMA
- Monitor and Control
- Telemetry Command and Control
- Test and Maintenance

This layer would be connected by a high speed Local Area Network (LAN) into a Network Control Centre (NCC) computer. The NCC would handle all of the common feature functions such as

- User Data Base Lists
- Overall Power Management
- Transponder Power and Bandwidth partitioning
- Call Statistics
- Billing Records
- Link with the other operators' NCS for data base verification
- Main operator interface

The NCC could also retain a floating pool of spare capacity, to add to any service during a busy period, in an overflow mode.

The advantage of making such a split is first of all that any signalling components already developed can be used in the lower layer. The NCC then becomes the large development item which incorporates the majority of the MSAT particular features. Even though the NCC will be a purpose built design, its internal structure should be modular, allowing a phased implementation.



This concept of a purpose built NCC, supported by dedicated front end processing units, minimizes schedule and risk. With an agreed LAN standard several independent initiatives can be undertaken, to provide the various lower layer functions. Each of these equipments should be able to provide its basic functions independent of the NCC, and so service can be provided as soon as possible. For example the Data Hub equipment and Aeronautical equipment are already well into the development process.

To implement the structure suggested above a fully centralized system could be employed as shown in Figure 5. In this system, one location for each of the satellite operators (TMI & AMSC) serves as the Network Control Station (NCS). This control station would contain all of the lower layer equipment, including the front end processors performing the Aeronautical Mobile Service DAMA function.

The main advantage of the fully centralized approach is that it provides the satellite operator with the greatest level of control over satellite resource. This ensures the most efficient use of Bandwidth and Power. It also produces the lowest recurring cost for Gateways and Base Stations. The operator retains the capability of providing other service providers with channels, on a pay as you use charge structure.

The disadvantages are that it restricts autonomous use of space segment by other service providers, for example Inmarsat Signatories, and in that sense it may prove impractical.

To give autonomy to the Inmarsat Signatories, the Aeronautical DAMA could be removed from the NCS and located on the Inmarsat Signatories' premises. This would require a lease arrangement to be put in place, and would allow no sharing between Aeronautical & Land Mobile services, with regards to power in the satellite. Power would be purchased and paid for whether used or not.

Finally Figure 6 shows a scheme most suitable, if space segment leasing becomes a dominant feature of MSAT operations. In this scheme many DAMA switches are allowed to be owned and operated by service providers, who have purchased a set amount of power and bandwidth. This includes a general aviation service run by an Inmarsat signatory, which does not follow the Inmarsat Aeronautical Standard. It also allows both MTS, MRS and MDS service to be run independently, by service providers who are not the satellite operator. These service providers do not pay as they use but purchase their own space segment. No central billing is done by the satellite operator and the function of the Satellite Operator NCC is simplified. If the satellite operator also provides service, he is seen by the network as just another space segment lessee. This scheme is similar to the way in which normal fixed satellite services are run today.

The major advantage of this approach is that it requires the least NCC development. It allows current technology to be used to the maximum extent. It allows entrepreneurs to implement their own service concepts easily, and gives all service providers autonomy.

The disadvantage is that in terms of resource sharing this approach uses the satellite in the least efficient manner.

Even though both operators will want to retain the same basic structure, their implementation may be somewhat different. In Canada where TMI has stated it wants to be a service provider the final configuration may look more like figure 5 with perhaps only a few autonomous lease arrangements. In the United States perhaps figure 6 will be a more likely approach.

## Conclusion

It can be seen that the Spar space segment design can be tailored to provide as much flexibility in power & bandwidth distribution as satellite operators require. It can also be seen that to realize that flexibility, a high degree of innovation and thought will need to be applied to the Ground Segment Infrastructure. A lot of previous work has been completed tackling the theoretical aspects of the Ground Segment and optimizing specific designs, protocols and modulation schemes. However, if the Ground Segment is not to be a holding item on service implementation, serious consideration will need to be given to technologies that are proven.

The prospect of Space Segment lease arrangements also will have a direct effect on any proposed ground architecture, and will also impact the type of monitoring system deployed by the satellite operator.

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- (5) V. Leung, A. Spolsky, M. Ali, G. Acres, Demand Assignment for Mobile Radio Networks over Satellite, IEEE 38th Vehicular Technology Conference, Philadelphia, Pa. 1988

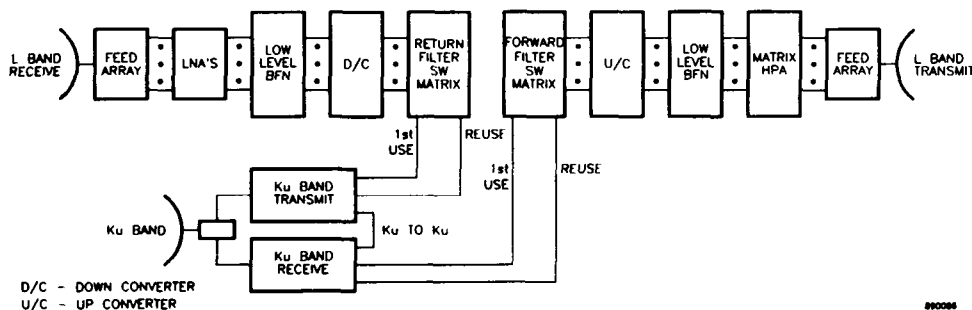


FIGURE 1: PAYLOAD BLOCK DIAGRAM

ORIGINAL PAGE IS  
OF POOR QUALITY

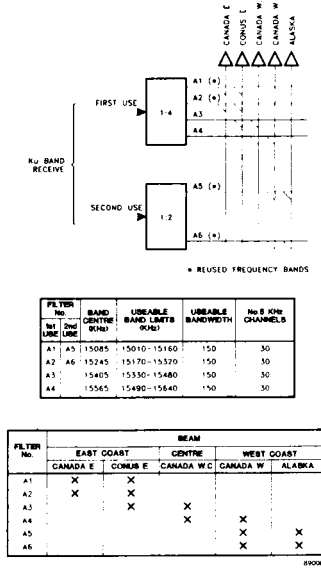


FIGURE 2: LIMITED FUNCTION FILTER SWITCH MATRIX

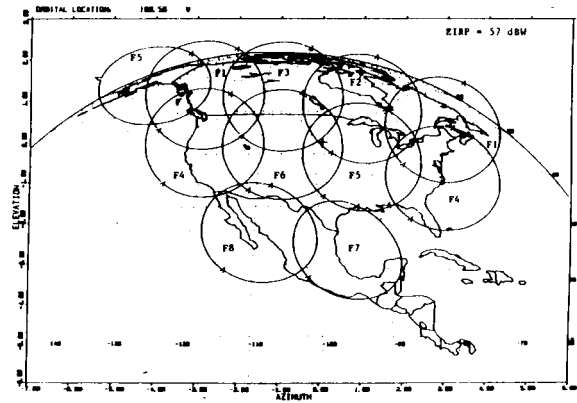


FIGURE 3: L BAND TRANSMIT COVERAGE PATTERN

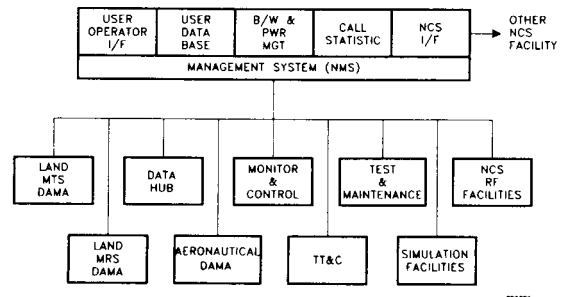


FIGURE 4: NETWORK MANAGEMENT TWO LAYER HIERARCHY

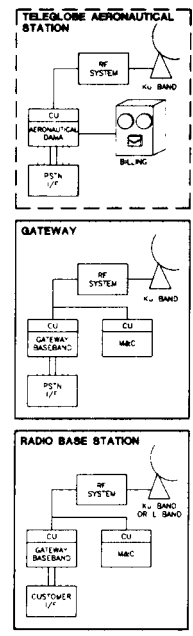


FIGURE 5: CENTRALIZED ARCHITECTURE

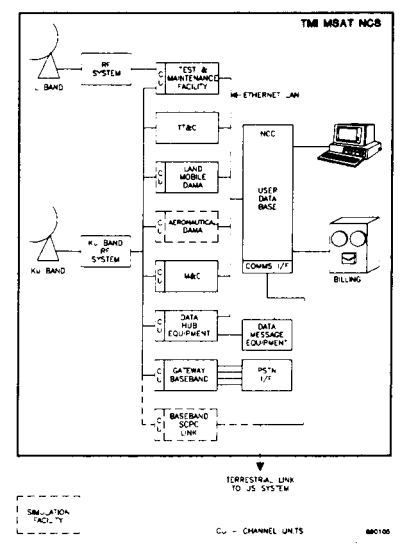


FIGURE 6: DISTRIBUTED ARCHITECTURE

