Chapter 45

Dynamic Resource Management in High Throughput Satellite with Multi Port Amplifier (MPA)

Sunil Panthi
University of California Irvine, Irvine, CA, USA

Ahmed M. Eltawil
University of California Irvine, Irvine, CA, USA

ABSTRACT

The demand for data capacity has been growing, especially in the aviation and maritime industries and is expected to continue to grow in the foreseeable future. The satellite industry is moving to High Throughput Satellite (HTS) that are characterized by large numbers of small spot beams, frequency reuse, higher Equivalent Isotropically Radiated Power (EIRP) and higher Gain to Noise Temperature (G/T) to meet growing capacity demand. Multi-Port Amplifiers (MPA) increase the flexibility of HTS systems by allowing capacity to be allocated dynamically based on changing demand. This will allow capacity requirements to be planned based on the sum of the requirements across all beams rather than the peaks in each HTS beam. The authors propose a ground based solution that will maximize resource utilization of an HTS with an MPA and deliver the capacity dynamically based on demand. Maritime, commercial aviation, satellite based cellular backhaul, and disaster recovery services are the main applications that can benefit from the solution they propose. The authors' results show significant reduction in the overall capacity requirements because of the more efficient utilization of the satellite resources.

INTRODUCTION

Satellite Communication Overview

Satellites have been providing services such as television broadcast, broadband internet, cellular back-haul, and intelligence gathering for many years. Communication satellites have traditionally been built

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with continental-scale wide beams. Wide beams have an advantage because of the large area they can cover - as much as 42% of the earth's surface from a single satellite geostationary orbit. However, low Equivalent Isotropically Radiated Power (EIRP) and Gain to Noise Temperature (G/T) are inherent in such wide beams and require larger terminal antennas to maintain the link and provide acceptable data rates. Applications of these satellites have been expanding in mobility including both commercial and government aviation and maritime vessels – all constrained in antenna size.

High Throughput Satellites (HTS)

The satellite industry has acknowledged the growth in demand and started adopting HTS architecture that has large numbers of small spot beams, reuse frequency across beams, and offer higher EIRP and G/T. Frequency reuse allows much more bandwidth to be supported within the same coverage area as wide beams. For example, Ku-band has frequency assigned for earth-to-space from 14.0 GHz to 14.5 GHz – a total 500 MHz band. A wide beam covering the size of a continent can deliver, in both vertical and horizontal polarization, capacity limited by a bandwidth of 2x500 MHz. An HTS with n beams and u-color reuse, and available bandwidth B, in both polarizations can deliver capacity with an effective bandwidth F_ϵ of:

$$F_\epsilon = 2n\frac{B}{u} \tag{1}$$

An HTS with 16 beams in a coverage area and 4-color reuse pattern can increase the available bandwidth by 4 fold relative to a wide beam satellite covering the same area. Mobility applications, constrained in terminal antenna size and challenged to operate in wide beam satellites, can offer service with a higher data rates with HTSs. An example of an HTS with 4-color reuse is shown in Figure 1.

Multi Port Amplifier (MPA)

While HTS architectures deliver higher throughput than wide beam satellite architectures today, they often have less flexibility to reallocate resources dynamically. The MPA overcomes the limitation on HTSs by adding high degree of flexibility in moving resources. MPAs allow an operator to buy a pool of bandwidth and power over a number of spot beams and distribute those resources based on time-varying demand.

An MPA consists of an Input Butler Matrix (IBM), High Power Amplifiers (HPAs), and an Output Butler Matrix (OBM) (Esteban et al., 2013). The size of the MPA is determined by the number of active amplifier paths ranging from 2 x 2 to 32 x 32 (Morris et al., 2015). The input signal is divided equally in the IBM, passes through all active amplifiers and is recombined in the OBM. The total output power at each output port is proportional to the input power at the corresponding input port, when operated in the linear range, and each signal may operate in the same frequency band with relatively high isolation between the ports. In the limit, the full power of all of the amplifiers may be directed to a single output port. The output powers across the ports may be allocated arbitrarily by controlling the input powers, drawing power from the aggregate power of all of the amplifiers in the MPA, thus allowing power and bandwidth to be flexibly allocated across the ports.