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Emerging technologies for communication satellite payloads

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ABSTRACT

Recent developments in payload designs will allow more flexible and efficient use of telecommunication satellites. Important modifications in repeater designs, antenna structures and spectrum policies open up exciting opportunities for GEO satellites to support a variety of emerging applications, ranging from telemedicine to real-time data transfer between LEO satellite and ground station. This study gives information about the emerging technologies in the design of communication satellites' transceiver subsystem and demonstrates the feasibility of using fiber optic links for the local oscillator distribution in future satellite payloads together with the optical inter-satellite link.

Contents

1. Introduction

Space technology is conservative in terms of modification, which needs a long heritage to be approved among the industry. However the system requirements coming from the satellite operators such as flexible power, flexible coverage, and flexible bandwidth drive the system developers to introduce new solutions both in satellite bus phase and payload phase. Flexibility needs are shown in Fig. 1.

For advancement, fiber optic solutions provide an attractive alternative to conventional RF distribution sub-system and harnesses; they may meet the low phase noise requirements, while ensuring drastic mass savings and suppressing isolation and EMI/EMC issues, requiring only low extra power consumption. For example, coaxial cables have a mass of about 53 g/m versus 4 g/m for qualified optical fibers. Aside the improvement in distribution, another concern is the feed design.

Space antenna feed systems are growing in terms of complexity, as mission requirements needed by customers are becoming more specific. The widening of frequency bandwidth, the frequency reusability, the increase of power handling as well as reduction of mass while reaching better RF performances are the goal and constraints in feed design. The use of efficient analysis and optimization tools is necessary to meet these aims. Today, simulation tools give accurate results for RF performances of single components. Thus, it is possible to investigate new structures and to significantly reduce the bread-boarding phase as well as the development cycle. The current trend is to integrate more and more components in the simulation in order to optimize the overall electrical performances of the feed chain. Again, compactness is required. Reconfigurable antennas for multimedia applications

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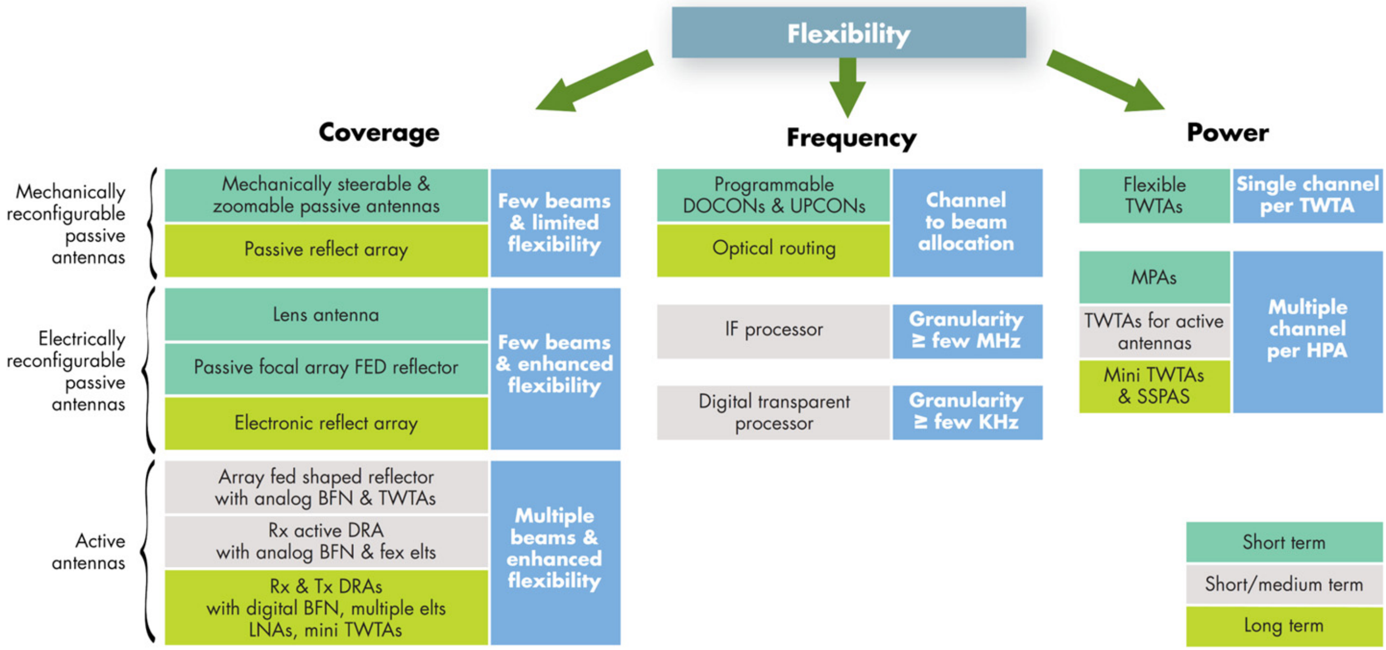

Fig. 1. Flexibility possibilities.

need compact feeds with numerous integrated components; as global RF chain performances are critical, optimization software shall easily handle the partitioning of the structure and improve those performances while reducing calculation time. Power handling capability is also a rising consideration as new payloads are required to support more channels and output power. Multipactor, PIM and thermal management have to be taken into account during the design phase. Finally, mass and volume reduction remain as constant tasks to be studied. Hence optical distribution helps in both to achieve these reductions and the increment in the performance of the RF chain. In this study, the advancements and current solutions utilized by the satellite developers are presented.

2. Design of power modules

2.1. Current status of TWTAs

At millimeter-wave bands, the performance of vacuum electronics devices is not likely to be matched by solid-state power amplifiers in the near future. Vacuum electronics amplifiers continue to play an important role in high-power transmitter applications. At microwave frequencies, recent advances in wide bandgap semiconductor devices such as GaN and power combining techniques are enabling SSPAs to challenge the power advantage of vacuum electronics amplifiers, but vacuum electronics devices still hold the efficiency edge even at these frequencies. At millimeter-wave bands, the performance of vacuum electronics devices is not likely to be matched by SSPAs in the near future. The use of linearization further enhances the efficiency edge of vacuum electronics amplifiers. The development of technology at the upper millimeter-wave and submillimeter-wave are enabled by cold cathode technologies and microfabrication techniques. Most microwave engineers fail to appreciate the capability, efficiency and reliability of vacuum electronics technology. Only vacuum electronic devices meet many of the demanding requirements for reliable performance. In the design of spaceborne high power transmitters, a strong emphasis is placed on minimizing the power consumption, applied voltage, size and weight of the amplifiers. For such application, where

Table 1
Comparison of TWTA and SSPA power capacity.

Frequency band	Max. TWTA power (W)	Max. SSPA power (W)
C	~2200	~1500
X	~2500	~1200
Ku	~1200	~500
Ka	~500	~50
Q	~200	~5

instantaneous bandwidth is also a requirement, helix and coupled-cavity TWTs are the devices of choice. The typical available powers for commercial satellite communication TWTAs and SSPAs are compared in Table 1.

Power advantage of TWTAs over SSPAs is significant, especially at the higher frequency bands. At the lower frequency bands, TWTAs are challenged by SSPAs. The linearity of a power amplifier is always of great importance. For communication applications, the TWTA has long been considered as a device with poor linearity compared to the SSPA. The general belief is that a TWTA must be backed-off 3–4 dB from saturation to achieve the same level of linearity as an SSPA. This is an incomplete statement. It is pointed out in [1] that the power consumed by a TWTA is usually less than that of an SSPA with only half of the rated RF power. As a result, for two amplifiers with the same total power consumption, a TWTA generally has more available linear power than an SSPA for most of the frequency band. The two amplifiers have the same linearity performance for lower-power and lower-frequency amplifiers only. Furthermore, the linearity of a TWTA can be improved much more by use of linearization than that of an SSPA. As a result, more of the TWTA's RF power that is lost due to output back-off is available as linear power.

Predistortion linearization is a simple and effective technique for improving the performance of both SSPAs and TWTAs [2]. Its effectiveness on TWTAs is more significant because of slow approach to saturation and the higher nonlinearity of the TWTA. It has been shown in [3] that by applying the fifth order linearization, it is possible to achieve less than 1 dB overall gain compression at saturation so that the combined transfer curve