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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

The application of the low earth orbit (LEO) small satellite constellation for satellite communication (SATCOM) has made significant and widespread contributions to society in various locations worldwide. This paper discusses two representative systems of this constellation: the earth exploration satellite service (EESS) and the high data rate SATCOM internet. The former provides global monitoring, benefiting early detection and preparation for terrestrial disasters, pollution, and other harmful phenomena on earth. The latter can handle the ever-increasing demand for high data rates and providing seamless connectivity, anytime and anywhere. Both systems are the two most important and popularly used SATCOM systems.

To fully leverage the advantages of the SATCOM using LEO small satellite constellation, the design of the transmitter (TX) must fulfill three fundamental requirements: high data throughput, low cost, and low power consumption. Achieving high data throughput is critical for the LEO small satellite SATCOM to keep up with the explosive increase in data demands from both EESS and the high data rate SATCOM internet. Additionally, low cost is a crucial consideration in the construction of the satellite constellation. The third crucial requirement is low-power consumption, as the trend towards smaller satellite bodies for cost reduction makes it necessary to minimize power consumption.

To achieve the research objectives of high data throughput, low cost, and low power consumption for the SATCOM using the LEO small satellite constellation, several challenges must be addressed. These challenges include implementing dual circular polarization, utilizing Ka-band frequency, utilizing CMOS technology, utilizing phased array technology, and developing deployable large-size antennas.

This dissertation presents several key techniques and solutions to achieve the high data throughput, low cost, and low power consumption for the realization of SATCOM using the LEO small satellite constellation. These include the load tuner, circular polarization calibration, dual/single circular polarization coupler, and systematic array design for low-power phased-array TX. Additionally, it discusses the implementation of dual circular polarization and Ka-band CMOS phased-array TX to achieve a higher data rate while maintaining low cost and power consumption. Lastly,

a new deployable phased array is presented and analyzed, which enhances space efficiency and reduces costs.

The mmWave load tuner could successfully recover the dropped power efficiency to the values more than 15 % from the 9% of dropped efficiency in minimum over the beam steering except for -50 degrees beam angle. These results show that the mmWave load tuner is the prominent power efficient system for SATCOM phased-array TX system.

The discussed circular polarization calibration technique dramatically improved the deteriorated cross polarization discrimination (XPD) to more than 32 dB from 21 dB XPD in maximum over the scan angle. Maximally, the circular polarization calibration technique achieved 48 dB of XPD. Furthermore, with the modulated signals, the proposed technique could achieve -24.8 dB of error vector magnitude (EVM) under 16-APSK dual circularly polarized transmitting mode. The result also proved that the proposed techniques are essential in SATCOM phased-array TX system.

To save power consumption, single/dual circular polarization coupler is proposed. The proposed single/dual circular polarization coupler saved -38% of the power compared to the conventional method in single circular polarization mode under similar gain and saturated output power level. In the unexpectable satellite environment, which requires switching between single circular polarization and dual circular polarization mode, dramatically saved power consumption by the proposed technique is helpful for power-efficient SATCOM phased-array TX system.

By aggressively exploiting large array gain, systematically, the proposed system could save the total power consumption compared to conventional systems under similar equivalent isotropically radiated power (EIRP) levels. The proposed system saved 2.3 times of power consumption compared to conventional phased-array TX system.

The proposed deployable phased-array TX with the new structural deployable substrate is analyzed and discussed, as well. With the proposed new structure, 15 times lower satellite launch cost is expected compared to conventional rigid phased-array system. Also, the lightweight liquid crystal polymer (LCP) reduced to 2.4 times lighter weight from the conventional rigid substrate solution. Thanks to the LCP solution, the proposed system achieved 0.82 kg/mm^2 of areal mass under 64-element array size and expected to have 0.089 kg of lightweight phased-array TX system under 4096-element array size assumption.

In summary, this dissertation presents various techniques and solutions to achieve high data throughput, low cost, and low power consumption for the implementation of the SATCOM utilizing LEO small satellite constellations. Analyses and measured results are well supporting the proposed techniques are prominent for high data throughput, low cost, and low power consumption SATCOM phased-array TX system.