A Novel Architecture of Radio Tracking System Based on Photonics

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Abstract. We propose a photonics-based novel architecture of radio tracking system in space applications. This system can operate in multiple frequency bands, implement various functions, and realize integrated, generalized, frequency–independent design. This new scheme can meet the needs of future space missions, and especially suitable for space tracking ship.

1. Introduction

The future space missions require that a single ground-based radio tracking system can support many types of mission, i.e., operate in multiple frequency bands, implement various functions and have large bandwidth[1].

In this background, the traditional electronics methodology faces great challenges. Firstly, each frequency band needs separate RF links and the system will be very bulky and complicated. Rotary joint is needed to transfer many different signals and the reliability will be very low especially in oceanic environment. Secondly, the system performance will be limited by the mutual interference between multiple frequencies and intended interference.

Furthermore, due to the large loss of the cables, there is no much degree of freedom of the processing units’ location.

The dynamic allocation of tracking equipment needs large-scale RF switch matrix, but as the operation frequency and the scale of the matrix rises, the insert loss will increase rapidly. The change of temperature will induce instability of phase and group delay. To compensate this loss, multi-stage amplifiers are usually adopted and more instability is induced. Besides, the isolation and interference problems are also significant.

To meet the need of deep space communication, a large G/T ratio is needed. To improve the G/T ratio, we can increase the antenna aperture, however, the effect-cost ratio is quite low. An alternative approach is antenna arraying but the large loss caused by the electrical cable must be overcome.

Microwave photonics is an interdisciplinary area that studies the interaction between microwave and optical signals[2], for applications such as broadband wireless access networks, sensor networks, radar, satellite communications, instrumentation, and warfare systems. In the past few years, there has been an increasing effort in researching new microwave photonics techniques for different applications.

Combining optics and radar together and applying microwave photonic in the development of new generation of radar is now a hot topic and shows great potential advantages[3,4].
2. System Design
In this project, we propose a novel photonics-based system which operates at several frequency bands simultaneously, realizes ultra-wide band and integrated design. The diagram of the proposed system is shown in figure 1.

![Diagram of photonics-based radio tracking system](image)

In this scheme, output signals from the LNA (Low-Noise Amplifier) are modulated to optical wave and mixed to a lower frequency, transferred through optical fiber by WDM (Wave Division Multiplex) to a photodetector. After being detected and sampled, the signals are sent to a generic signal processing unit in which the downlink information from the satellite, and the range, range rate, direction of the satellite are extract.

The generic signal processing unit also generate the uplink data and modulates the optic-electronic oscillator. The RF signal is transmitted to the satellite by the antenna.

3. Performance Analysis and Potential Advantages
The proposed scheme can realize frequency-independent and ultra-width design, has high ability of anti-interference and high stability.

Compared with conventional approach, the RF links are significantly simplified. Complicated up-converters/down-converts for each band are replaced by a single optical mixer and the development cost is thus decreased and the reliability is improved.

High loss, phase drifting and amplitude fluctuating caused by electrical cable are overcame and a large-scale low-loss RF switch matrix based on photonics can be realized.

In sequential tone ranging, tone dispersion in the channel affects greatly the ranging accuracy. Since the fiber has very large bandwidth, this effect can be eased and the ranging accuracy will be improved. Compared with electronic oscillator, optoelectronic oscillator has very low phase noise and a higher accuracy of range rate can be achieved[1]. Phase noise also increase the bit error rate, so a lower phase noise can also improve the communication/telemetry performance[1].

4. Challenges
To realize a system mentioned above, there are still many challenges.

Firstly, a rotary joint that can transfer optical signal and large-power RF signal simultaneously must be developed. This rotary joint differs from existing ones and might be very difficult to design.

Secondly, the difference signal in the tracking channel is very low, especially when the antenna axis is pointing at the satellite, the difference signal will be approximate zero. How to transfer such a weak signal through fiber is a problem must be solved.

References
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