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The Concept of Photonics-Based Virtual Ground Tracking Station

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Abstract. In this paper, we propose the concept of virtual ground tracking station for space missions. Based on microwave photonics, the virtual tracking station can realize spatial diversity, antenna arraying, dynamic resource allocation and distributed signal processing. Compared with conventional design, the flexibility, efficiency and performance can be significantly improved.

1. Introduction

For long time application of ground tracking station in our country is the single station mode. That is a firm mode using multiband radio space TT&C equipment such as S C X Ka. All single station equipments must have Uplink and Downlink channel, terminal unit of signal and data. It needs not only plenty of money human resources and maintenance cost but also more modification investments to meet demand of growing techniques.

Even under such background of high investment, the whole coverage rate by ground tracking station is just 20%～30%, far behind rate of near 90% by space tracking station. So a new plan of big center small station has been put forward ten year ago. Its essential meaning is to move terminal unit of signal and data from station to center and station is just served as transparent channel of microwave[1]. Such layout not only makes the new mode of unmanned remote control settled, but also realizes unified processing information by same center without intermediate links in order to enhance the effectiveness highly.

This paper develops a new approach to the plan of big center small station that using photonics technique to construct a total new ground tracking mode named virtual TT&C which breaks the boundary between stations and centers. By the reflexive configuration between not the virtual station but the virtual point and the physical center, the new approach will make ground tracking improved toward higher level of distributed collaborativeTT&C.

2. General Design Considerations of Virtual TT&C

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2.1. Basic Concept Of Virtual TT&C

In this scheme, tracking equipments can be dynamically allocated, combined, networked and operate in a distributed/cooperative fashion. The basis for achieving these special characteristics is constructing the intensive optical networks between base points and centers. For example, 200～300 base points which are non-substantieve fiber optical node in the whole local area of our country is being built and 5 existing space tracking control center which serve as substantieve entity will be kept to play a role of switching center in the whole network.

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In the new design, existing ground tracking stations are connected with optical fibres， and all connected with the control centre. Every antenna modulates its received signal on the optical fiber[2] and transferred to the control centre where signal processing and data processing are implemented. In addition, control center must have plenty of front-end vehicular equipments which keep only a small quantity of radio frequency(RF) unit such as Antenna Servo Feed System, Low Noise Amplifier Power Amplifier. According to the principal of Radio Over Fiber system microwave signal is transimtted by optical fiber under the direct modulation of optical signal carrier by photo-electric and electric-photo conversion[2]. The concept of ground station is virtualized by such a function reconfiguration so as to name virtual TT&C.The diagram of virtual tracking system is shown in Figure.1.

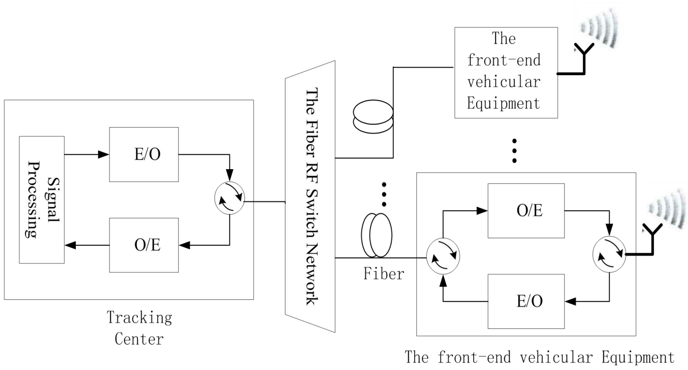

Figure 1. Principle of inveracious TT&C system

2.2. Technical Advantage

There are two technical advantage of virtual TT&C. One is optimal allocation of physical factors in ground tracking resources by dynamic allocating position, quantity and specific type of front-end vehicular equipments based on its own features of aircraft, just like flight characteristics, load feature, frequency band and modulation features, etc. The second advantage is downsizing staff massively so it makes human factors in ground tracking resources optimate too.

2.3. Design Considerations

Downlink channel of front-end vehicular equipments are composed of the antenna, the source feed network, Low Noise Amplifier and the optical transmitter. Solid integrated connection is appropriate to the source feed network and Low Noise Amplifier to reduce insertion loss. There are three key links which is the optical transmitter, the fiber slip-ring and the fiber RF switch network on the whole system design.

For the optical transmitter which refers to electric-photo conversion unit(E/O), although common intensity modulated direct detection（IM/DD）is simple, but the influence of chirp effects on the RF signal phase is severe for F-P cavity has more longitudianl-mode laser, the wider spectral bandwidth, and the larger injection current. So IM/DD is unfit for long-distance transmission which exeeds 500km from base points and centers. On the other hand, virtual TT&C must alter from point-to-point into optical interconnection(EPON or GPON) which needs plenty of optical cross-connection in the intermediate switching node. It will changes bandwidth great, therefore orienting the future external modulation is suitable. Single longitudinal mode laser（SLM）plus Mach-Zehnder mode filter(MZM) might be considered. Planar waveguide integrated electro absorption modulated laser (EML) is recommended for the reason that EML has become commercialized, higher Side-Mode Suppression Ratio by engraving the Prague grating and the electric absorption waveguide on the same substrate. In addition, this structure can be no need for MZM which benefits for installation on the antenna front-end as a result of its smaller sized.

As the E/O coversnion unit installed on the antenna front-end and together rotating with the antenna, simultaneously the location of the fiber optic connector terminal is fixed, there needs a fiber slip-ring to connect the antenna motion and static part. But The fiber coupling efficiency is greatly affected by the degree of alignment of two fiber end faces, so there is a very high requirement for the machining accuracy of the antenna structure. At present the more mature solution is using a self focusing lens to convert the conical light into the parallel light to increase the coupling efficiency. There are documents presented using Finel lens to produce multiple reflection optical path between the axis and off-axis to improve the coupling efficiency further[3].

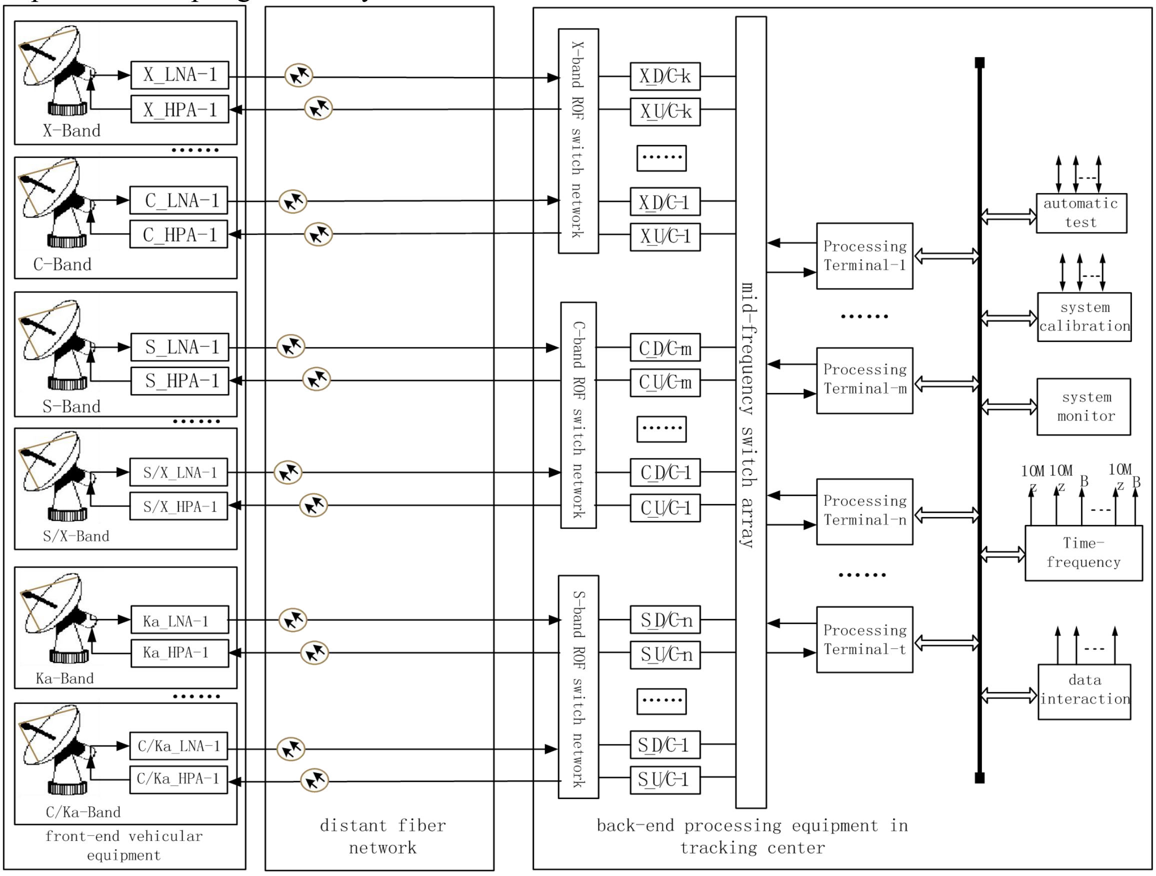

Figure 2. The typical composition frame of RF resources reconstruction system

As before said, the reflexive configuration by virtual TT&C is mainly reflected in the dynamic configuration and invocation between the front-end vehicular equipments and the back-end processing unit in the tracking center. This configuration and invocation is realized through the fiber RF switch network. As shown in Figure.2, the fiber RF switch network Directly connect the other end of the optical fiber, This means that its switching function can only be done in the optical domain. It is not complicated achieving it in the technology as long as the star optical coupler or a plurality of ordinary 2 x 2 directional coupler, a plurality of light switches can take a variety of complex optical switching array. The degree of commercialization of the above coupler and optical switch is very high. Need to focus on is the insertion loss, channel isolation and dispersion characteristics. As the ordinary double cone star coupler is limited by the light splitting ratio, its insertion loss and channel isolation is restricted each other that is not conducive to the realization of the scale of 20 x 20 optical switching network. So the array waveguide gratingstar coupler (AWG) which is the new integrated optical results may considered. As its input, output waveguide normal direction is directly to the other side of the phase center, the power of the free space coupling region can be well distributed to each branch, especially to the edge branch. So under the same insertion loss, the channel isolation degree can be improved by 10 dB.

The dispersion characteristics of the coupler will give a large phase and delay variation to the optical signal, so the timing precision of microwave signal will be influenced. It has little effect on the microwave signal of C and S band but it can not be ignored of Ka, X band. At present, the effective method is to use the Ka or X frequency conversion to C or S band to transmit. This, of course, is at the expense of increasing the complexity of the device.

3. Conclusion

Virtual TT&C proposed in this paper orienting in the new direction of "big center small station", breakthrough the current fixed station mode of construction bottleneck in accordance with the specific characteristics of the aircraft to dynamically set and control resources. On the overall design method, the microwave photonic technology is put forward, which is directly on the upper and lower link of the RF terminal to complete the microwave signal of the electro optic and photoelectric conversion. In detail design process it put forward three following measures.
(1) Single longitudinal mode modulation of microwave signal is achieved by using EML laser.
(2) Fiber slip rings is achieved by using the self focusing lens or lens Finel multire flection technique.
(3) AWG star coupler is used to realize optical signal switching array of 20 * 20 or above, and the effect of switching element dispersion on phase and delay is overcome by using the Ka or X frequency band to C or S band.

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