Cofinanciado por la Unión Europea

Generalitat de Catalunya
Departament d'Empresa i Treball
Secretaria de Polítiques Digitals

SPECIFICATION SHEET

SUPPLY, INSTALLATION AND COMMISSIONING OF A QUANTUM KEY DISTRIBUTION RECEIVER FOR EAGLE-1 SATELLITE CONNECTIONS FOR ICFO, WITHIN THE FRAMEWORK OF THE < IBERIAN QCI > PROJECT OF THE EUROPEAN COMMISSION'S < CONNECTING EUROPE FACILITIES > PROGRAM.

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CLAUSE 1. Object of the contract

The object of the contract is the supply, installation and starting-up of a Quantum Key Distribution Receiver (QKD RX) for EAGLE-1 satellite connections at ICFO capable of operating quantum communication protocols in the metropolitan area of Barcelona.

CLAUSE 2. Needs to satisfy

ICFO Optoelectronics Group (OptoGroup) actively participates in the development and demonstrations of quantum communication technologies in practical applications and real-world environment within the "*Iberian QCI*" project implementation of the EuroQCI initiative, whose objective is to deploy cross-border quantum connectivity between Spain and Portugal by employing satellite links or ground links.

Quantum communication protocols performances for Quantum Key Distribution (QKD) are limited by the great losses across fiber-based optical networks over long distances, making the use of trusted-nodes or quantum-repeaters unavoidable with the current state-of-the-art technology.

On the other hand, satellite-based optical links with the ground allow long distance quantum communication due to the lower losses in the free-space optical transmission. To validate quantum satellite-to-ground links, it is essential to integrate a Quantum Key Distribution Receiver (QKD RX) capable of supporting the reception, detection and resolution of QKD protocols based on specific encodings into ICFO Optical Ground Station.

The QKD RX will need to enable demonstrations and use-cases with advanced relative-phase-encoding BB84-decoy QKD protocols running over optical links in the C-band established with satellites orbiting in the LEO orbit under real environmental conditions, ensuring compliance with the requirements of the QKD Transmitter (QKD TX) used as payload in the satellite in the LEO orbit. In particular, demonstrations with soon-to-be-launched LEO satellite EAGLE-1 will need to be executed to establish quantum-safe connections between cross-border nodes not only across Spain and Portugal, but spanning the whole European Union. Therefore, the QKD RX specifications will need to be compliant and compatible with EAGLE-1 consortium prescriptions and ICFO Optical Ground Station (OGS).

CLAUSE 3. QKD RX Essential Requirements

We hereby define QKD RX as the assembled components (systems and subsystems) necessary to receive, detect and resolve the EAGLE-1 QKD downlink signal. The bidder proposal shall contain the following mandatory requirements:

Functional Requirements:

1. **Communication Capabilities**
    a. The QKD RX must operate with the relative-phase-encoding BB84 with decoy states protocol established by the EAGLE-1 consortium.
    b. The QKD RX must operate in the C-Band, and more specifically at 1565.50 nm (ITU-T #15) wavelength used as a downlink quantum channel by the EAGLE-1 QKD Transmitter.
    c. The QKD RX design parameters must respect the EAGLE-1 relative-phase-encoding BB84 with decoy states protocol parameters (see the document "The Eagle-1 QKD protocol - Phase encoded BB84 decoy in a practical satellite QKD Application").
    d. The QKD RX must operate at a QKD downlink signal single pulse rate of 2.5GHz.

e. The QKD RX must operate with LEO orbit altitude between 500km and 600km (EAGLE-1 orbit).
f. The QKD RX must integrate into ICFO Optical Ground Station (OGS): it must be able to accept QKD downlink signals from the Single-Mode Polarization-Maintaining fiber with FC/APC connector and to connect via ethernet interfaces to the OGS Control System.
g. The QKD RX must receive an external clock signal to lock the internal time-tagger.
h. The QKD RX must always assure compatibility with EAGLE-1 QKD Processing Software (QKD Processing P/F) provided by SES in the Network Certification process (i.e. the mandatory process described in document EAGLE1-XXXXX-CEF-PRS-TCO_V0.2_ESA-EC-CEF which is required to be completed successfully before a user Ground Terminal can request access to the EAGLE-1 airtime service).

2. **Capabilities for System Stability**
   a. The QKD RX must be protected by a system structure able to endure controlled atmospheric condition within the ranges of 10°C – 30°C and temperature fluctuations of max ±5°C /60min.
   b. The QKD RX must be protected or allow protection against and endure electric discharges.
   c. The QKD RX system structure must endure small earthquakes and unexpected external vibrations caused by human intervention.
   d. The QKD RX must be installable in a standard 19-inch rack.

3. **Subsystems Capabilities**
   a. The QKD RX must be endowed with an active phase locking mechanism able to keep the relative phase of the received pulses stable (with a maximum overall phase jitter of $\pi/50$) against random drifts.
   b. The QKD RX must be endowed with a clock recovery system able to synchronize with the EAGLE-1 QKD signal and resolve the downlink QKD signal's weak coherent pulses: this recovery system must be compatible with the downlink QKD signal frame structure reported in document "The Eagle-1 QKD protocol - Phase encoded BB84 decoy in a practical satellite QKD Application".
   c. The QKD RX must include a SNSPD system with at least four coupled channels each working at minimum 80% efficiency around wavelength of 1550nm, with dead-time of less-equal than 80ns, a jitter full-width-half-maximum of less-equal than 50ps, a max count rate of at least 5 MCps and dark-count rate lower than 20Hz.
   d. The interferometers must provide high-contrast interference with visibility typically around 98%, and in any case not below 97% under nominal operating conditions. The supplier shall provide supporting test data and describe the procedures required to maintain this performance.
   e. The maximum total loss introduced by the QKD RX (excluding input fiber interface coupling loss and including detection efficiency) must not exceed 7dB.

Operational Requirements:

4. **Control and Monitoring**
   a. The QKD RX must allow remote-control operation with a control software.
   b. The QKD RX must allow real-time monitoring of performances and systems / subsystems status.
   c. The QKD RX must upgradable to ensure future compliance with the document "EAGLE-1-

xxxx-QGS-ICD-TCO Monitoring & Control ICD For Ground Terminal", especially to start its operations in coordination with OGS control software.

5. **Interfaces**
   a. The QKD RX must have a fiber coupling interface going from the ICFO's OGS to the QKD RX: this interface must comply with the requirements of chapter "3.2 I/F B Fibre coupling" of the document "EAGLE1-00746-SYS-ICD-TCO-Ground Terminal Interface Control Document for the European Commission".
   b. The QKD RX must have a data interface going from the QKD RX to the QKD Processing P/F software provided by SES: this interface must comply with requirements of chapter "3.9 I/F H QKD receiver message" of the document "EAGLE1-00746-SYS-ICD-TCO-Ground Terminal Interface Control Document for the European Commission".
   c. The QKD RX must have a data interface for Monitoring and Control: this interface must comply with requirements of chapter "3.5 I/F E Monitoring & Control" of the document "EAGLE1-00746-SYS-ICD-TCO-Ground Terminal Interface Control Document for the European Commission".
   d. The proposal must contain continuous support and update of the previous listed interfaces to maintain compatibility with EAGLE-1 QKD Processing Software (QKD Processing P/F) provided by SES according with future versions of the document "EAGLE1-00746-SYS-ICD-TCO-Ground Terminal Interface Control Document for the European Commission".

Regulatory Requirements:

6. **Test & Certification**
   a. Factory Acceptance Tests (FAT) must be carried out before the final delivery.
   b. A Site Acceptance Test (SAT) must be carried out: due to the current unavailability or limited access to the EAGLE-1 airtime, the SAT must be conducted by directly connecting a QKD source emulating the quantum signal emitted by EAGLE-1 (including the phase and temporal frame structure described in the document "The Eagle-1 QKD protocol - Phase encoded BB84 decoy in a practical satellite QKD Application") to the interface described at bullet 3.5.a. The SAT must take place at the time of delivery.
   c. Support for the SES's Network Certification process (the mandatory process described in document EAGLE1-XXXXX-CEF-PRS-TCO_V0.2_ESA-EC-CEF which is required to be completed successfully before a user Ground Terminal can request access to the EAGLE-1 airtime service and SES's Optical Ground Stations network) must be provided in case issues concerning the QKD RX are found during the Phase-2 of the process.

7. **Documents**
   a. A complete set of manuals, drawings, schematics and layouts about system assembly and configuration must be provided.
   b. A complete systems user manual, including routine servicing, troubleshooting and basic repairs must be provided.
   c. A systems components spare list, specifying quantity, manufacturer, part number, etc must be provided.
   d. All the above documentation will be supplied in English, in electronic format (pdf in USB drive) and in printed paper copy.
   e. Draft document of complete technical project must be provided.

8. **Compliance**
    a. The bidder must be based in an EU-27 country, in compliance with the requirements established in the Connecting Europe Facility Programme Security declaration.
    b. The bidder must comply with export regulations controls of the European Union for the procurement of components, sub-systems and the delivery of equipment.
    c. The QKD RX must not make use of ITAR restricted items.
    d. The QKD RX must comply with IEC 60825 for laser safety, or equivalent.

CLAUSE 4. QKD RX Non-essential System Requirements

The QKD RX system will be used to establish a communication channel for EAGLE-1 quantum key distribution protocols at an operating wavelength in the C-band (in downlink direction). The QKD RX will require a interferometers system with driving electronics, a detection system, a time-tagging module, a control system (internal PC of FPGA), a rack-mountable chassis structure, OGS to detectors fiber interfaces, ethernet data interfaces and systems to mitigate random phase drifts in the interferometers branches and synchronize the QKD RX with the incoming QKD signal.

The QKD RX proposal **may contain** the following components (systems and sub-systems) and relative requirements that will be evaluated according as established in Annex 2:

Test and Validation:

1. The proposal will include FAT and SAT plans using a QKD Test source emulating the EAGLE-1 QKD TX signal frame structure reported in document "The Eagle-1 QKD protocol - Phase encoded BB84 decoy in a practical satellite QKD Application". This QKD Test source will validate also the phase stabilization and synchronization functionalities reported at bullet 3.3.a and 3.3.b.

Detectors:

2. The proposal will include a SNSPD with four Polarization-Maintaining coupled channels.
3. The proposal will include a rack-mountable SNSPD.
4. The proposal will include a SNSPD with demonstrated detectors' jitter lower than 25ps.

Downlink Filter:

5. The proposal will include a 0.3nm bandwidth filter unit to separate the downlink QKD signal at 1565.5nm from the downlink classical signal at 1553.33nm, ensuring the level of attenuation/isolation of the QKD signal as per SES recommendations in document "EAGLE1-00149-SYS-SPC-FAU QKD Protocol Design Definition File for the European Commission".

CLAUSE 5. Additional Requirements

We will evaluate the following optional improvements included in the proposal as stated in Annex 2:

Upgradability:

QKD Schemes

We will evaluate the level of support of the system to polarization encoding multi-purpose architecture that can be extended to implement additional future applications: additional modules may be already integrated in the system, enabling the implementation of different QKD schemes, such as polarization-encoding schemes, or may be added seamlessly in the future thanks to system characteristics.

The software and firmware upgradability to enable access to the new functionalities will be positively evaluated.

Support:

SES Network Certification Process

The evaluation will consider the extent to which the bidder provides support for the SES Network Certification Process (NCP) in terms of remote or in-presence support, temporal extension of the support during the NCP, responsivity of the found-problem solving process, beyond just the resolution of hardware and software defects resulting from issues identified during Phase 2. Extended support covering the full Network Certification Process will be positively evaluated.

CLAUSE 6. Transportation, installation and start-up

6.1. The proposal will include transportation to ICFO's facilities including insurance and all export/import and customs duties.

6.2. The machine will be placed in the selected location by within the facilities it has in the metropolitan area of Barcelona. Contract winner will cover all costs, organization and coordination of machine placement, including any required specialized equipment or vehicle, and any required component disassembly and reassembly for system unloading and transportation inside the building.

6.3. Onsite system installation and training to ICFO personnel included: included 3-day training of the full QKD RX use and process to ICFO users and specific maintenance and service training to ICFO lab technicians at ICFO's facilities.

CLAUSE 7. Warranty and Follow-on Support

a. A **Minimum 2-year Full Warranty** on all parts and components of the system irrespective of the manufacturer. The warranty will include the replacement of any faulty or damaged part(s) during the normal use of the system, no matter the manufacturer of the component(s). It will cover any cost related with the disassembly, transportation, reparation and re-assembly of the damaged component(s), including all travelling and living costs of the required service engineer(s). An onsite repair, or a justified alternative to reduce the system down time to the minimum, will always be the first service option. A team of properly qualified and skilled service engineers will have to be available. **Additional years of warranty will be evaluated positively as stated in the Annex núm. 3.**
b. System support: By phone and e-mail with a response within 48 hours. Emergency visit after a system breakdown within 10 working days.
c. Application support within 10 working days, in case of software issues.
d. Product Support Helpdesk for software and firmware updates or bug fixing must be available since the delivery of the product to the end of *Iberian QCI* project, approximately in June 2029.

CLAUSE 8. Delivery time

The QKD RX should be delivered within 24 weeks starting from the signature of the contract.

Delivery time is defined as the time elapsed since the signature of the contract until the system delivery at ICFO facilities. It includes the manufacture of the system, the factory acceptance test at company's premises, the transportation, installation and commissioning.

CLAUSE 9. Target price

The target price for the system is 700.000,00€ (VAT excluded).

Castelldefels, on the date of its digital signature

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