

SECTION 27 37 00 – MULTI-BAND MOBILE RADIO COMMUNICATION SYSTEMS

1.01 SUMMARY:

- A. ^{A17}**Scope:** Scope of work shall be in accordance with Paragraph 1.01 D. of Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), as required, to extend radio coverage to limited, difficult, and confined areas in parts of the Works.^{A17} This Section of the Employer's Requirements shall be read in conjunction with the Sections listed in Table 27 37 00-1.^{A16}

- B. **Related Sections:**

TABLE 27 37 00-1: ^{A9} Related Sections ^{A9}			
1.	Section 01 81 26	-	Communications, Control, Safety, and Security Systems.
2.	Section 25 11 00	-	Data Processing Equipment.
3.	Section 26 33 00	-	Direct Current Equipment.
4.	Section 27 11 16	-	Cabinets, Racks, Frames, and Enclosures.
^{A3} 5.	Section 27 21 00	-	Data Communications Equipment ^{A3}
^{A3} 6. ^{A3}	Section 27 31 23	-	IP-based Telephone Systems.
^{A3} 7. ^{A3}	Section 27 31 33	-	Radio-Telephone Communications Console Systems
^{A3} 8. ^{A3}	Section 33 81 13	-	Communications Transmission Towers.
^{A3} 9. ^{A3}	Section 33 82 00	-	Cabling for Underground Communications Outside Plant.
^{A3} 10. ^{A3}	Section 35 12 00	-	Vessel Detection Systems.

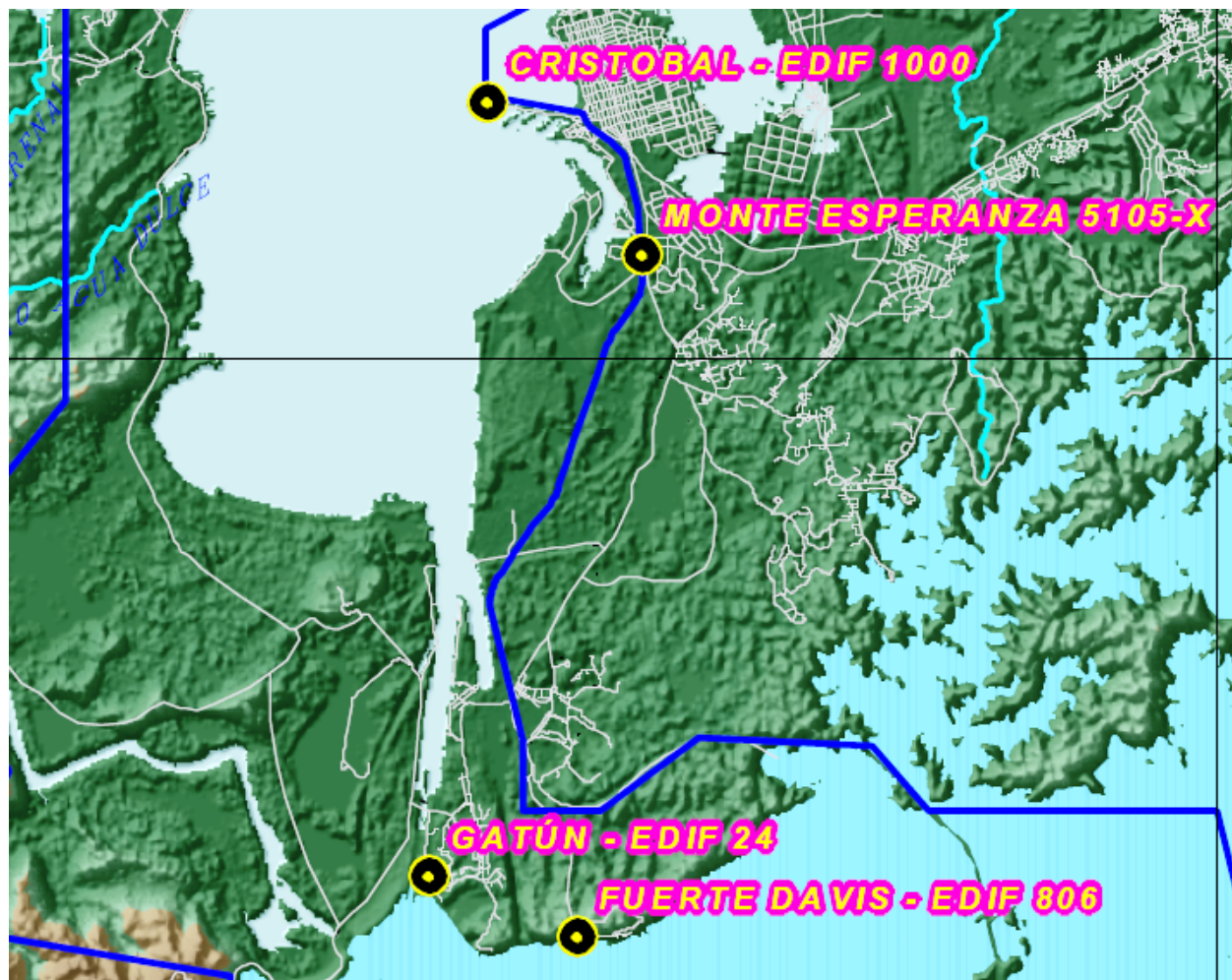
- C. ^{A3}**Items by the Employer:**

1. Unless otherwise specified, the Employer will furnish portable radio apparatus (including mobile radios, trunk radios, cellular phones, ^{A3} [personal communications service \(PCS\) phones, and WiFi or WiMax terminals](#)) and base radios as required for radio communications in open areas.
- ^{A9}2. Note that this Contract excludes radio base stations for communications in wide open areas, and that the Contractor shall furnish WiFi or WiMax terminals for VDS in accordance with Section 27 11 00 (*Data Communications Equipment*).^{A9}

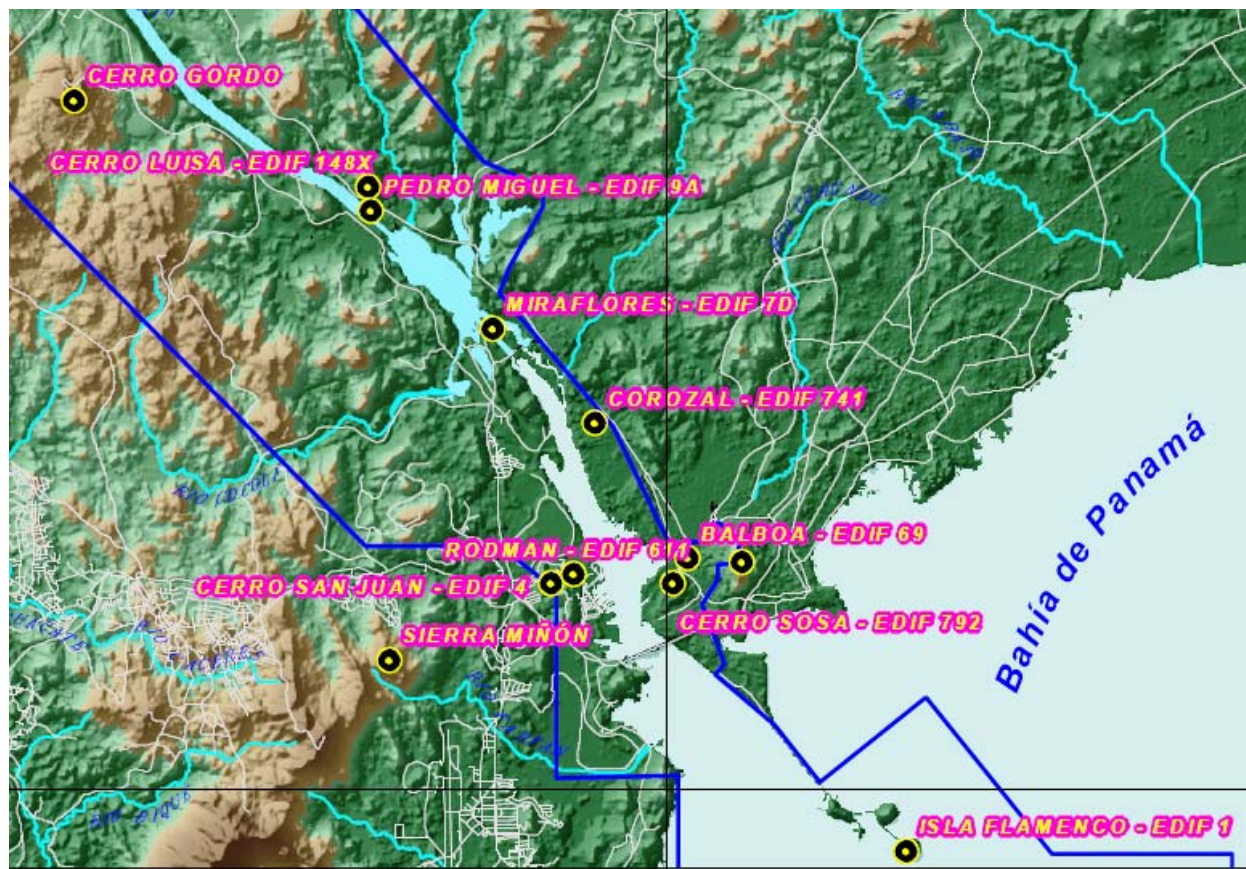
1.02 REFERENCE:

- A. **Applicable Publications:** Refer to Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), ^{A9}Paragraph^{A9} 1.02.
- B. **Frequency Assignments:** The Employer has already been assigned UHF frequencies for operations of the new locks. Detailed information will be furnished to the Contractor.
- C. ^{A9}**Relevant Radio Site Data Relevant to New Locks:** The areas for new locks are covered from the Employer telecommunication sites listed and shown below. Received signal strength depends on antenna gain and radiation pattern, distance, frequency, transmission line losses, and transmitter combiner losses.^{A9}

^{A9} TABLE 27 37 00-2: Employer Radio Site Data Relevant to New Locks							
Site	Building	Side	UTM* Northing	UTM* Easting	Elevation (m)	Tower (m)	Installed Services
Ancon Hill	140	Pacific	990330	659457	176.1	68.6	Tetra, UHF, VHF
Cerro Gordo	19	Pacific	999184.6	646643.7	285	91.4	Tetra, UHF, VHF
Cerro Luisa	41	Pacific	997539	652297	179	48.8	UHF, VHF
Corozal West	741	Pacific	992998	656631	16.8	22.9	Tetra, UHF, VHF
Ft. Davis	806	Atlantic	1023975	620225	75	62.5	UHF, VHF
Gatun	24	Atlantic	1024740	618402	25.9	67.1	Tetra, UHF, VHF
Mt. Hope	5105X	Atlantic	1032258	621007	4.7	48.8	Tetra, UHF, VHF
Sosa Hill	792B	Pacific	989930	658165	111.3	45.7	UHF, VHF ^{A9}
* Universal Transverse Mercator							



^{A9}**Figure 27 37 00-1: Employer radio sites on the Atlantic side** ^{A9}



^{A9}Figure 27 37 00-2: Employer's radio sites on the Pacific side^{A9}

- D. ^{A9}**Existing Employer Equipment:** Typical Employer's equipment for various radio services are as follows:^{A9}

^{A9}Table 27 37 00-3: Existing Employer's Radio Equipment

Installed Services	Manufacturer	Typical Output Power (W)
Tetra	Rohde & Schwartz	25
UHF	Motorola & Tait	60
VHF	Motorola & Tait	60
WiFi	Cisco	0.1
WiMax	Redline	0.2 ^{A9}

1.03 REQUIREMENTS:

A. General Requirements:

- The ^{A9}Contractor^{A9} shall meet all applicable requirements of Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), ^{A9}Paragraph^{A9} 1.03, including safety and protection against lightning and RFI ([radio-frequency interference](#)).

2. The ^{A9}Contractor^{A9} shall provide fixed infrastructure to extend the coverage of Employer's radio and WiFi systems, as well as public cellular and personal communications service (PCS) telephony systems. WiMAX is optional.
3. Radio-communications systems shall provide adequate, nearly uniform, radio coverage, as follows:
 - a. **Permanent Installation:** Areas shall include cable galleries (i.e., below switchgear in electrical rooms), Crossunders, passageways (i.e., to lock gate flotation tanks), tunnels, valve pits, and vertical shafts.
 - b. **Provisions for Temporary Installations:** Areas shall include culverts (when dry for maintenance).
4. The systems shall be wideband and designed to accommodate the expansion of additional mobile radio equipment and the integration future services while reducing the need for multiple cabinets. Such expansion and integration shall be possible by sharing a common radiating and distribution system without expensive replacement of RF equipment.

B. Wireless Data Transmission Requirements:

1. ^{A3}Note that the Contractor shall furnish WiFi or WiMax systems to transmit VDS data to tugs and transiting vessels in the third set of locks areas, in accordance with Sections 27 21 00 (*Data Communications Equipment*) and 35 12 00 (*Vessel Detection Systems*). These systems shall include antennas, transmission lines, transmitters, wireless terminals, and any other necessary devices. ^{A3}

C. Equipment and Materials:

1. Base Amplifiers:

- a. Amplifiers shall be modular, bidirectional, and as required to compensate for losses from cable and couplers. Amplifiers shall offset excessive transmission path losses simultaneously in both the forward and reverse paths (net overall gain of 0 dB).
- b. "Direct RF Amplifier" or Class A linear amplifiers are preferable.
- c. ^{A17}Duplex filtering shall be used as required to separate transmit and receive frequencies. ^{A17} Stable filters shall be used to process the radio signals as required.
- d. Amplifiers shall be capable of accepting modules for redundant configuration, pilot signal, control and status, and other services not initially provided.
- e. Amplifiers shall accept a single DC input voltage through the transmission line, and include internal DC-DC converter(s) as required.

The converter(s) shall provide isolation from noise and voltage spikes, and change the DC supply to the required internal operating voltages.

- f. ^{A17}The ^{A9}Contractor^{A9} shall submit the following information for review:^{A17} The amplifier's maximum RF input level, third order intercept point (in dBm) and saturated output power (in mW or dBm).
- g. Unless otherwise recommended by the Contractor and reviewed by the Employer's Representative, amplifiers shall have the following or better characteristics:

^{A9}**TABLE 27 37 00-4: Base Amplifier Characteristics**^{A9}

Power Gain	20 to 30 dB, adjustable
Power Output Range	0 to 10 dBm per carrier
Spacing	In 20 dB increments
Bandwidth	As required

2. **Antennas:**

- a. Antennas shall be ^{A10}TIA 329^{A10} compliant, and be furnished as required for the services specified on ^{A9}Subparagraph 1.04 A.1.^{A9}
- b. Antennas shall have adequate coverage in the applicable frequency bands.

3. **Connectors:** Shall be standard items for the intended frequency bands and cable type.

4. **Fasteners:** All metal shall be stainless steel, unless otherwise recommended by the Contractor and reviewed by the Employer's Representative.

5. **Grounding Kits:**

- a. Grounding kits shall have a solid (not braided) copper strap to prevent water retention and minimize corrosion problems due to wicking. Braided straps are unacceptable.
- b. Kits shall meet the applicable requirements of MIL-STD 188-124.

6. **Leaky Coaxial Cables:**

- a. Leaky or radiating coaxial cable shall be of the intermittent-slot type, NFPA 70 Article 820-53 type CATVP compliant, and with a rugged, flame retardant and heat resistant construction.
- b. Such cables shall have low sensitivity to salt water deposits and its expected increase in attenuation and coupling loss shall be low.
- c. Due to possible "end effects" at the terminations, the ^{A9}Contractor^{A9} shall indicate with his design the recommended distance between a tunnel

opening and the cable termination point, as required to insure an acceptable isolation. With its inherent coupling loss, leaky feeder cable shall provide 60 dB or better isolation.

d. Cables shall have the following or better characteristics:

^{A9} TABLE 27 37 00-5: Leaky Coaxial Cable Characteristics ^{A9}			
Electrical Characteristics:			
Attenuation (Nominal) ¹	At 150 MHz	3.69 dB/100 m	(1.12 dB/100 ft)
	At 450 MHz	7.0 dB/100 m	(2.13 dB/100 ft)
	At 900 MHz	10.6 dB/100 m	(3.25 dB/100 ft)
	At 1,700 MHz	16.58 dB/100 m	(5.05 dB/100 ft)
	At 2,400 MHz	21.95 dB/100 m	(6.69 dB/100 ft)
Coupling Loss ²		70 dB in frequency bands of interest between 100 and2,600 MHz	
Power Rating		4,000 Watts peak	
VSWR		1.3:1 (17.692 dBRL)	
Mechanical and Physical Characteristics:			
Center Conductor		Copper or copper clad aluminum with tubular shape	
Dielectric		Low loss foam polyethylene specially formulated to be low in hygroscopic residue to minimize attenuation increases over the life of the system due to water absorption.	
Flooding Compound		Non-flammable and as required to preclude water migration, should the jacket become damaged and tunnels or Crossunders be accidentally flooded. Placed between the outer conductor and the jacket. It is understood that flooding compound may not be required, depending on its fire retardant characteristics and other characteristics that the insulating tape barrier may have.	
Insulating Barrier		Double-wrapped (flame barrier) tape around the outer conductor to prevent the dielectric material from leaking through the slots under fire conditions.	
Jacket		Black polyethylene to provide protection during handling and installation. It shall be fire-retardant, non-halogenated.	
Outer Diameter		22 mm (7/8 in) nominal, or larger	
Shield		Corrugated copper with specially designed slots to allow energy to couple into and out of the cable. It shall also present a formidable barrier against rodent attack for a long-life, maintenance-free system.	
Other		Transmission line strength and flexibility shall be suitable for tunnel installations.	

e. ^{A9} (Reserved) ^{A9}.

¹ *Attenuation* shall be nominal and relative to cable mounted to insulated fastener on concrete, assuming 51 mm (2 in) or larger standoff.

² *Coupling loss* (measured in dB at a 6 m or 20 ft) shall be understood as the average difference between signal level in the cable and the signal received by a 0 dB gain antenna, assuming worst case slot orientation.

7. **Line Amplifiers:**

- a. Line amplifiers shall be modular and bidirectional. "Direct RF Amplifier" or Class A Linear amplifiers are preferable.
- b. Duplex filtering shall be used to separate transmit and receive frequencies. Stable filters shall be used to process the radio signals as required.
- c. The amplifiers shall be capable of accepting modules for redundant configuration, pilot signal, control and status, and other services not initially provided.
- d. The amplifiers shall accept a single DC input voltage through the transmission line, and include internal DC-DC converter(s). The converter(s) shall provide isolation from noise and voltage spikes, and change the DC supply to the required internal operating voltages.
- e. ^{A17}The Contractor shall furnish the following information with their calculations:^{A17} The amplifier's maximum RF input level, third order intercept point (in dBm) and saturated output power (in dBm).
- f. ^{A17}Unless otherwise recommended by the Contractor and reviewed by the Employer's Representative, amplifiers shall have the following or better characteristics:^{A17}

Power Gain	20 to 30 dB, adjustable
Power Output Range	0 to 10 dBm per carrier
Spacing	In 20 dB increments

8. **Miscellaneous Items:** The ^{A9}Contractor ^{A9} shall furnished combiners, couplers, hybrids, and other parts as required.

9. **Power Supplies:**

- a. The Contractor shall furnish a DC feed assembly and a system power supply for bidirectional amplifiers, as required.
- b. Power supplies shall derive power from DC source specified on Section 26 33 00 (*Direct Current Equipment*), or 120 VAC, 60 Hz source, then convert it to the required DC voltage, and insert DC power in the transmission lines through the DC feed assembly.
- c. The Contractor shall consider the total power required by the applicable devices and the **current x resistance (IR)** voltage drop of the transmission lines.

10. **Stand-Offs:**
 - a. Stand-offs shall be suitable for maintaining an adequate separation between leaky coax cables and adjacent surfaces. ^{A17}Such separation shall be no less than 51 mm (2 in).^{A17}
 - b. Units shall be insulated, quick, and self-locking hangers with at least two locking teeth.
11. **Towers:** ^{A17}Shall be in accordance with Section 33 81 13 (*Communications Transmission Towers*), and as high as required for the necessary receiving antennas.^{A17}
12. **Transmission Lines:**
 - a. Transmission lines shall be low loss, foam dielectric, and with length as required to connect antennas and leaky coaxial cables to transmitting and receiving equipment.
 - b. Lines shall meet the requirements of EIA 199, EIA 225, or both. Flexible lines are preferable.
 - c. ^{A9}Radio transmission lines shall be un-pressurized.^{A9}
- D. **Software:** Shall be as required for system management.
- E. **Installation:**
 1. **General:**
 - a. Cables and transmission lines shall be installed so that splices, where strictly necessary, be done only in approved inspection chambers, boxes, connectors, and other suitable devices.
 - b. Installation shall be permanent for above water and non-flooded sites such as Crossunders, tunnels, and vertical shafts. Permanent installations shall have provisions for temporary installations as required elsewhere.
 - c. Installations in culverts and RG habitats shall be temporary (only for use while doing maintenance work).
 - d. Leaky coax and transmission line bends shall be made using approved bending tools, as recommended by the manufacturer.
 2. **Antennas:** Shall be installed in new towers in accordance with Section 33 81 13 (*Communications Transmission Towers*).

3. **Base Amplifiers:**

- a. Amplifiers shall be installed in the communications equipment room in the main control building at each lock, and where required elsewhere.
- b. Unless otherwise recommended and justified by the ^{A9}Contractor ^{A9}, the system shall be divided in 0 dB net gain sections (amplifier gain offsets line losses).
- c. The number of amplifiers shall be kept as low as possible. Repeating amplifiers shall be connected in daisy chain(s), as required.
- d. Each amplifier shall be housed in a single, key lockable, NEMA 4X stainless steel enclosure per NEMA 250 and permitting mounting directly to walls.

4. **Hoisting Grips:** Shall be furnished for installation of transmission lines in vertical paths.

5. **Leaky Coaxial Cables:**

- a. This or better technology shall be used in Crossunders, rolling gate slots (bottom), and tunnels.
- b. Installation shall use appropriate standoffs at periodic intervals, as recommended by the manufacturer.

6. **Line Amplifiers:**

- a. Repeating amplifiers shall be connected in daisy chain(s), as required. The number of amplifiers shall be kept as low as possible.
- b. Each amplifier shall be housed in a single, key lockable, NEMA 4X stainless steel enclosure per NEMA 250, permitting mounting directly to walls.

7. **Stand-offs:** Units shall be installed at 1.5 meter or shorter intervals, unless otherwise recommended by the Contractor and reviewed by the Employer's Representative.

8. **Transmission Lines (non-leaky):**

- a. Transmission lines in towers shall be fixed to a vertical waveguide/transmission line support ladder.
- b. Transmission lines in other areas shall be installed on horizontal cable trays.

1.04 DESIGN CRITERIA/SYSTEM PERFORMANCE:

A. General:

1. **Problem to be Solved:** Multi-band mobile radio communications systems shall solve the following business needs:
 - a. Provide bandwidth and signal strength as required to extend radio communications to Crossunders and confined spaces.
 - b. Provide reliable communication service, especially during emergencies.
2. **Restrictions to be Considered:** (reserved)

B. Design Criteria:

1. Systems shall be wideband and allow bidirectional radio communications, with coherent bandwidth capability between 100 and 2,600 MHz (and optionally 3,700 MHz). Initial coverage shall include, but not be limited to, the following services and frequency bands:
 - a. Cellular telephony (824-849 and 869-894 MHz).
 - b. Next generation services available in Panama by the time the third set of locks open to business.
 - c. PCS telephony (1,850-1,990 MHz), to become available tentatively in 2009.
 - d. TETRA trunk radio (380-400 MHz).
 - e. UHF radio (450-470 and 500-510 MHz).
 - f. VHF radio (148-174 MHz).
 - g. WiFi (2,400-2,484 MHz) data communications and WLAN services.
 - h. WiMAX (3,400-3,700 MHz) optionally, in accordance with IEEE 802.16e.
2. ^{A17}Unless otherwise recommended by the Contractor and reviewed by the Employer’s Representative, the following impedance matching criteria shall be met at all frequencies of interest: ^{A17}

<u>VSWR</u>	<u>Return Loss (dBRL)</u>	<u>Device Type</u>
1.106:1	25.963	RF Transmission Line (non-leaky)
1.20:1	20.828	Active Devices
1.25:1	19.085	Other Passive Devices

3. The design shall consider sharing antennas whenever possible by using the following means: appropriate filters, isolators, circulators, directional couplers, splitters/combiners, transmitter combiners, receiver multi-couplers, duplexers,

and any other necessary items. This applies to transmitters, receivers, translators, amplifiers, demodulators, and repeaters.

4. Fiber optic distribution is acceptable provided that the ^{A9}Contractor ^{A9} furnishes the appropriate fiber/RF converters, and fibers in accordance with Section 33 82 00 (*Cabling for Underground Communications Outside Plant*).
5. ^{A17}The Contractor shall submit a Path Calculation Sheet for review of each radio link when RF signals are to be sent over the air. ^{A17} The sheets shall include, but not be limited to, the following data as applicable at the lowest and highest frequencies for each applicable RF band:
 - a. Minimum transmitter, amplifier, or repeater output power (dBm).
 - b. Transmission line types, lengths (m), and losses (dB).
 - c. Connector losses (dB).
 - d. Mismatch losses (dB).
 - e. Circulator, isolator, band pass filter, duplexer, and attenuator insertion losses (dB).
 - f. Transmitter combiner and receiver multi-coupler losses (dB)
 - g. (Pre) amplifiers and line amplifier gain (dB).
 - h. Antenna sizes in mm (ft), heights (m), and gain (dB).
 - i. Free space loss (dB).
 - j. Recommended field allowance (dB).
 - k. Obstruction losses (dB).
 - l. Other losses (dB) due to beam tilt or azimuth with respect to directional antenna beam.
 - m. Calculated medium received power (dBm), fade margin (dB), S/N (dB), and system availability (% of time).
 - n. Receiver sensitivity, threshold, or mute point (dBm).
 - o. System bandwidth and operating frequencies of interest (MHz).
 - p. Site names, elevations (m), and coordinates.
 - q. Path length (m) and azimuth with respect to true north.
 - r. Tower heights (m).
 - s. Horizontal and vertical radiation pattern plots for each type of antenna.
6. RF system operating margin shall be 15 dB or better.
7. The variation of signal strength at the input of a receiver shall not exceed 22 dB when a portable moves from end-to-end of any section.

8. The design shall use a suitable “system use factor” in the calculations, to consider possible variations in coupling loss.
 - a. Unless otherwise recommended by the ^{A9}Contractor ^{A9} and reviewed by the Employer’s Representative, minimum system use factor shall be 10 and 15 dB in the forward and reverse paths, respectively, excluding the effect of geometric cross sections in tunnels.
 - b. ^{A17}The Contractor shall consider the estimated effect on coupling losses due to Crossunders, culverts, and tunnels’ cross sections. ^{A17}
9. Line amplifiers shall be used to offset excessive transmission path losses simultaneously in both the forward and reverse paths. Net overall gain shall be as close as possible to 0 dB.
10. Systems shall have test points available for measuring RF power without interruption to system operation.
11. System coverage shall include areas specified as permanent and temporary installations in ^{A9}Subparagraph 1.03 A.3. ^{A9}

C. **System Performance:**

1. **Availability:** System availability shall be 99.998% or better. Therefore, system theoretical unavailability shall not exceed 0.002% of time, or approximately 10.5 minutes per year.
2. **Leaky Coaxial Cables:**
 - a. Leaky cables shall appear to the base station(s) as an extended antenna, and shall allow a controlled portion of the transmitted signals to radiate along its length and couple to receivers in close proximity. Conversely, signals transmitted near a leaky cable shall couple to it and be carried back to the base station (repeater) site.
 - b. Leaky cables shall radiate horizontally and vertically polarized signals. Random changes in polarization from horizontal to vertical, if any, shall have a negligible effect.
 - c. Leaky cables shall be usable with portable radio and wireless device antennas oriented in any direction, and shall have slots oriented so that cable alignment is unnecessary.

1.05 SUBMITTALS: The following shall be submitted for substantiation purposes:

- A. **Design:** The following shall be in accordance with Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), ^{A9}Subparagraph 1.05 D: ^{A9}
 1. Calculations, including path calculation sheets and system availability.

2. CPM diagram, with monthly updates.
3. Defects, Reliability, Availability, and Corrective Actions System (DRACAS) scheme to be implemented as a part of the Systems Assurance regime.
4. Descriptive literature.
5. Drawings.
6. Protection methods for corrosion, ESD, fungus/humidity, lightning/surge, power distortion and harmonics, radio-frequency interference/electromagnetic interference (RFI/EMI), thermal, and vibration.
7. Quality assurance and control plans.
8. Radio system calculations.
9. Reliability, Availability, Maintainability, and Safety (RAMS) reports on the design.
10. Specifications.
11. SWOT analysis.

B. Re-submittals Just Prior to Purchasing Materials: All items in A. above that have changed from original submittal shall be resubmitted in a Design Conference in accordance with Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), Paragraph 1.05.

C. Right after FQCT:

1. Test reports.

D. Upon Receipt of Shipped Items in Panama:

1. Instruction manuals for administration, installation, maintenance, and operation.
2. Packing lists.

E. Prior to Issuance of Taking-Over Certificate:

1. As-built drawings.
2. List of recommended spare parts.
3. Software licenses.
4. Test reports.
5. Training services.

1.06 QUALITY ASSURANCE: Shall include the following in accordance with Section 01 81 26 (*Communications, Control, Safety, and Security Systems*), ^{A9}Paragraph ^{A9} 1.06:

A. Factory Quality Control Tests (FQCT).

- B. Training Services for no less than eight (8) Employer collaborators.
- C. Final Field Inspection Tests (FFIT).
- D. Spare Parts.
- E. Technical Support.
- F. Warranty.

END OF SECTION