Exhibit R
Photovoltaic Array Evaluation for Communication Systems Spohnheimer Consulting

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Issue: Assess if power conversion equipment for large (utility scale) photovoltaic (PV or solar) arrays will generate electrical noise that will potentially affect common 2-way radio systems such as those used by fire departments, 911 call centers, and business users. (Electrical noise is a generic term covering a wide range of frequencies, and includes Radio Frequency Interference (RFI), also sometimes referred to as Electromagnetic Interference (EMI).)

Background: Solar panels generate direct current (DC) power that must be converted to alternating current (AC) for use by commercial and consumer applications. Commonly, a power inverter system as large as several megawatts is used to perform this task, and both magnetic and electrical fields are produced in the process. In the U.S., the power created is 60 Hz (line frequency), characterized as extremely low frequency (ELF).

ELF currents create magnetic fields which decrease rapidly with distance from the conductors. As an example, for high voltage (e.g, 400 kV) towers/lines, studies recommend homes with continuous occupant exposure should be at least 150 meters away. This is a relatively small distance for most solar installations, and magnetic fields themselves do not create electrical noise.

However, in contrast to magnetic fields, higher-frequency electrical noise (e.g., RFI in the VHF and UHF frequency ranges, typically between 136 and 520 MHz for common 2-way systems) caused by multiples or harmonics of power conversion switching circuits and transient electrical effects have the potential to affect reception communications frequencies.

Analysis: Very large solar array power conversion systems are installed at numerous existing locations within the United States. From the installations it is clear that, unless large currents are involved in unshielded (non-metallic) conduits, magnetic effects are expected and known to be negligible beyond a nominal 330 feet.

Commonly, the medium-voltage (typically under 2,000 volts) power conversion circuitry is completely enclosed within large metal cabinets, including the transformer(s) used to convert solar panel voltages to higher voltage level needed for distribution. See **Figure 1** for a typical large-scale PV installation example. Such equipment will have relevant certifications including those from the National Electric Code, Underwriter's Laboratory (UL), and the North American Electric Reliability Corporation (NERC). The collector and distribution power conductors are usually installed underground using Direct Earth Burial (DEB) cables or in above-ground metallic conduits.

RFI must be radiated by much higher frequencies than the 60 Hz line frequency to affect the referenced radio systems. Harmonic (multiples of the 60 Hz primary frequency) testing of the example conversion equipment shows that higher frequency components in the resulting output

current are under 5% of the 60 Hz current levels, for frequencies above the 25th harmonic or 1500 Hz. This frequency is nominally five orders of magnitude (or a factor of 100,000) lower than those radio frequencies used for common communications equipment. As a result, RFI radiation in the 150-520 MHz range is shown to be minimal.

Figure 1: Example of typical large-scale PV inverter installation

External to the power conversion system, a large high-voltage transformer will increase the 60 Hz power to distribution voltage levels (e.g, 240 KV). This last voltage conversion is accomplished without using switching or electronics circuits by traditional transformer step-up action relying solely on magnetic coupling between windings without electronic noise generation.

For reference, numerous solar array installations already exist near and on public and military airports which rely on similar frequencies (i.e., 108 - 400 MHz) for navigation and Air Traffic Control communications. In Palmdale, CA, the arrays are approximately 5000' from the runway. Helicopter approaches to a practice runway directly overfly the arrays at several hundred feet altitude. At the Manchester Airport in New Hampshire, the solar installation is on the airport parking garage approximately 400-500' from the closest taxiways and the Airport Traffic Control Tower. At the San Diego International Airport (KSAN), the arrays are mounted on the roofs of large aircraft hangars only 100' from active aircraft ramps and about 1000' from Runway 27. For these examples, the Air Traffic Control communications are unaffected.

Conclusion: Well-designed and -constructed PV installations of industrial size present minimal risk to operation of typical communications services using the VHF and UHF frequency bands due to radio frequency or electromagnetic interference.

L. Nelson Spohnheimer
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Spohnheimer Consulting Airspace Systems, LLC

L. Nelson Spohnheimer

Summary:

Fifty years of professional experience in circuit, system, and installation design, facility siting, alignment, flight inspection, maintenance and testing, and operational application of navigation and communications facilities. Extensive formal and informal instructional experience.

Technical Education/Training

B.S.E.E Electrical Engineering, 1969, Iowa State University, MCL
National Science Foundation Studies, State University of Iowa
National Merit Scholar
Amateur Radio Operator, W7KVI

Professional Organizations & Awards

Institute of Navigation
Employee of Year Nomination, Federal Executive Board, 1983
FAA Employee of Year, Managerial/Professional, 1985
DOT Secretary's Award for Meritorious Achievement, 1986
FAA National Honorary Awards for Excellence, Mentoring, 1992
FAA Regional Administrator's Award, Scientific Excellence, 1994
FAA Regional Administrator's Award, Career Achievement, 2004

Specialization

Ground-based Navigation Aids & Air-Ground Communications
Siting, Design, Installation, Alignment & Integration,
Flight Testing, Operation and Maintenance Policy, Instructor
Global Positioning System Augmentation
Maintenance, Certification, System Operation Policy
Low-frequency, VHF, UHF signal propagation
Litigation support, FAA and U.S. Dept. of Justice
International Civil Aviation Organization (ICAO) Committees

Consultancies

Communications Engineering – Preparation of License Applications to Federal Communications Commission for Cellular, Paging, and Two-Way Companies, 1980 – 1990

Spohnheimer Consulting – Siting, Installation, Testing, Optimization, Operational Application, Maintenance, Training on Airspace Systems, 2005-Present

Recent Technical Papers (published and presented, partial list)

- Critical and Sensitive areas of ILS and their 3rd Dimension - Examples, Effects, and Proposals, 20th International Flight Inspection Symposium, Monterey, CA, 2018 ((co-author Dr. Gerhard Greving, Navcom Consult, Steinheim, Germany)

- ATC-Systems and Wind-Turbines: Statusof Numerical Simulations and Flight Measurements - Evaluation and Systematic results of Examples, 19th International Flight Inspection Symposium, Belgrade, Serbia, 2016 (co-author Dr. Gerhard Greving, Navcom Consult, Marbach, Germany)

- Recent Issues in Performance Prediction and Flight Inspection Measurements, 18th International Flight Inspection Symposium, Oklahoma City, Oklahoma, 2014 (co-author Dr. Gerhard Greving, Navcom Consult, Marbach, Germany)

- Challenges in Near-Threshold Flight Inspection Measurements, 17th International Flight Inspection Symposium, Braunschweig, Germany, 2012 (co-author Dr. Gerhard Greving, Navcom Consult, Marbach, Germany)

Professional History:

September, 2005, to Present: Managing Partner, Spohnheimer Consulting Airspace Systems, LLC, dba Spohnheimer Consulting

1995 to September, 2005: Federal Aviation Administration (FAA),
National Resource Engineer for Navigation

Provide engineering support to national and all regional FAA offices on a wide variety of technical issues, such as . .

- Investigating and solving unusual signal-in-space performance problems for navigation aids and air-ground communications equipment and systems
- Investigating and solving airborne measurement problems resulting from interoperability issues between avionics and ground-based navigation equipment
- Serving as National Airway Facility technical liaison to FAA's Flight Inspection Organization
- Serving as FAA national Member of International Civil Aviation Organization (ICAO) Navigation Systems Panel (NSP) Technical Work and Study Groups
- Preparing and reviewing specifications for national procurement programs such as Category III Instrument Landing Systems (ILS), Portable ILS Receivers, Space-Based Augmentation Systems
- Preparing and reviewing maintenance policy for ground and space-based navigation systems
- Serving as Subject Matter Expert to National Policy Team on FAA maintenance policy for all ground-based equipment
- Serving as a core group member (4 total) to write FAA's national facility technical evaluation program order
- Organizing and hosting recurring National Flight Inspection Symposia
- Conducting design reviews on new navigation aid systems for FAA Type Approval, Non-Federal, and FAA Takeover certifications
- Serving as Project engineer for specifying, testing, fielding, and training on the Navigational Aid Signal Evaluator, a portable airborne engineering measurements package for ground navigation aids
- Presenting technical seminars on navigation aids and air-ground communications engineering principles to technician and engineer audiences for FAA, U.S. Air Force, U.S. Army
- Developing and Presenting recurring Increasing National Airspace System Knowledge seminars, to over 3000 FAA Specialists
- Providing litigation support on engineering issues in aircraft accidents – prepare fact witnesses, testify as expert witness
- Providing engineering support on navigation-related aircraft accident investigations, to U.S. Air Force Accident Investigation Board (Bosnia "Ron Brown" T-43) and National Transportation Safety Board (Korean Air Guam 747)
- Serving as Northwest Mountain Region Airway Facilities Aircraft Accident Representative and Subject-Matter Expert to national Aircraft Accident Program Office

1979 to 1995 Federal Aviation Administration, Special Projects Engineer; Supervisor, Navigation & Communication Engineering Section

1969 to 1979 RACON, Inc., Chief Engineer, Seattle, WA; Motorola Inc., Senior Design Engineer, Fort Lauderdale, Florida; Texas Instruments Inc., Systems Engineer, Senior Design, and Design Engineer

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Summary: Application - 21 of 30 (Exhibit R – Photovoltaic Array Evaluation for Communication Systems) electronically filed by Christine M.T. Pirik on behalf of Marion County Solar Project, LLC