# Assessing VHF Band Interference in Qatar in Support of Radar Subsurface Probing of Aquifers

Abunada, Abdularahman ; Pierce, Iestyn; Khattab, Tamer ; Zorba, Nizar ; Heggy, Essam

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Abdulrahman Abunada & Iestyn Pierce
*School of Computer Sicense & Electronic Engineering*
*Bangor University*
Bangor LL57 1UT United Kingdom
a_abunada@ieee.org
i.pierce@bangor.ac.uk

Tamer Khattab & Nizar Zorba
*IIPL Lab, Electrical Engineering*
*Qatar University*
Doha, Qatar
tkhattab@ieee.org, nizarz@qu.edu.qa

Essam Heggy
*Electrical and Computer Engineering*
*University of Southern California*
Los Angeles, CA, USA
heggy@usc.edu

***Abstract*—High temperatures, low precipitation rates and dry desert lands prevent the existence of resources such as freshwater rivers, springs and lakes in Qatar. The only natural sources of fresh water are underground aquifers. Furthermore, extracting water from naturally-occurring underground water accumulation reservoirs can be challenging, because these reservoirs cannot exist 'anywhere', but rather within certain areas and depths below the surface. The amount of water in these reservoirs is unknown. It is therefore important to identify parameters to best utilise this scarce resource. Because of the importance of underground water resources, various technologies are employed globally to investigate and search for underground water. This research is part of the DesertSEA experiment, a national project in which Qatar is partnering with several US universities and NASA for the concept study of an airborne ground sounding radar (AGSR) to be used for shallow aquifer characterization. The successful operation of AGSR requires a surface interference survey using an interference sensing model (ISM) to measure surface interference above the ground surface within the VHF frequency band from 150 MHz to 200 MHz. This frequency is used to operate the transceiver sub-component on AGSR. The ISM is deployed in five locations, which have been identified based on geological estimations. The output data is recorded along with the measurement conditions to contribute to the understanding the nature of RF activities in the five locations.**

***Keywords — Interference Sensing Model, Frequency, Radar, Detection, Spectrum,***

## I. Introduction

Qatar suffers from a shortage of drinkable water resources due to the hot weather and salty underground water [1]. However, aquifers are stored in some locations in the middle of desert lands. Discovering the caves or wells that contain fresh water is not an easy process and requires the use of technologies, which will be identified later in this report. According to locally gathered statistics in Qatar, underground water levels are decreasing with time. The underground water reservoirs, where the underground water stored, are discharged when water is extracted for agricultural abstractions, flowing to the sea through underground channels or municipal and industrial abstractions. The discharged water per year outweighs the water charged into the underground reservoirs per year. The charging process occurs either by water injection, recharge from rainfall, influence from neighbouring countries, or recharge from wells and irrigation. The following table shows the statistical values for all the charging and discharging operations from 2008 to 2014 [1].

TABLE I.
Water Charging/Discharging (in Million M3 Unit) in Underground accumulations 2008 to 2014 [1]

| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|
| **Influence from neighbouring countries** | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| **Municipal & industrial abstractions** | -22.5 | -18.6 | -19.1 | -19.8 | -19.9 | -20.3 | -20.7 |
| **Agricultural abstractions** | -226 | -227.8 | -228.9 | -229.5 | -230 | -230 | -230 |
| **Flowing to the sea** | -18 | -18 | -18 | -18 | -18 | -18 | -18 |
| **Wells and irrigation recharge** | 67.1 | 70.1 | 70.1 | 70.1 | 70.1 | 82.66 | 82.66 |
| **Water injection** | 6.8 | 24.5 | 26.2 | 26.2 | 24.8 | 35.6 | 43.5 |
| **Rainfall recharge** | 26.8 | 65.5 | 21.1 | 65.6 | 63.3 | 56.7 | 39.8 |
| **Water balance** | **-158** | **-99.4** | **-140.5** | **-94.9** | **-120.6** | **-91.2** | **-100.5** |

Table I shows clearly that Qatar is losing underground water every year, and these underground water losses are liable to continue in the coming few years, especially with the increase in the Qatar population. Based on the numbers shown in the table, it is necessary for Qatar to develop a sustainability plan to save and protect the underground water sources. This is especially true now that fresh water sources have become a global concern, when 26% of the world population at risk of not being able to access clean water resources, according to the World Health Organization (WHO) [2].

## II. Problem Definition & Proposed Solution

An Airborne Ground Sounding Radar (AGSR) is used to experimentally study pre-defined locations in the middle vertical line crossing the State of Qatar. The results of the AGSR experiments are expected to help the researchers and scientists who are exploring and verifying the existence of fresh underground water. A transmitter of Radio Frequency (RF) signals will be implemented and connected to a transmitter antenna, which will be operating at a frequency range of 150 MHz to 200 MHz. This is the scale of the main project: however, this research will focus only on designing and implementing an Interference Sensing Model (ISM), which can scan the RF signals generated from different signal sources (if any) within the defined frequency range, for the defined locations that the AGSR is aimed to study. Practical measurements will be taken to analyse the level of the RF interference on the ground at five different locations. The research outcomes will help in implementing and programming the transmitter and receiver of the radar.

## III. STATE OF THE ART IN UNDERGROUND WATER DETECTION

Several countries have invested in the technologies used in underground water detection and worked to secure, protect and develop the facilities and assets of this industry [3]. Several technologies are used in this field, each with different implementation approaches and operating principles. The characteristics, advantages and disadvantages of some of these technologies are listed below.

### *A. Electric Resistivity Tomography (ERT)*

The Electrical Resistivity Tomography (ERT) conceptually follows Ohm's law. That is, resistivity "Ω" is the variable, and its value is based on the type of the objects, liquid and materials stored underground. The value of resistivity is determined by placing four metal sticks in the ground, injecting Direct Current (DC) in the ground through the two outer metals sticks, and measuring the potential difference created by the current flowing through the underground layers [4]. A study case took place in Egypt, for underground water discovery with further investigations in the resistivity values characterization and water level identification can be found in [5]. The following figure presents the operating principle of the ERT method, in a simple configuration.

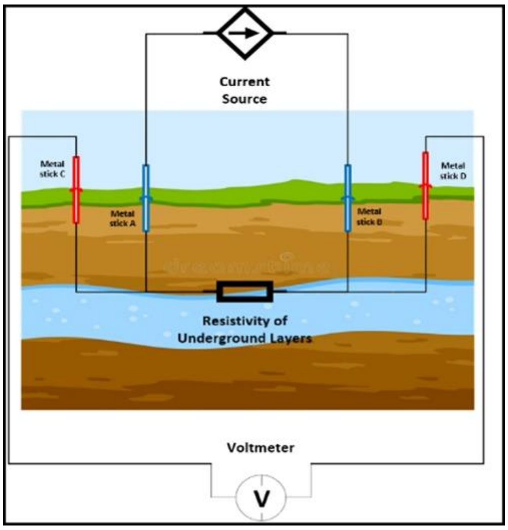


Fig. 1. System configuration for ERT method

In Fig.1, the resistance component represents a variable resistance for the resistivity of the ground layers, which might vary based on the nature of the lower layers – that is, whether the layers are composed of sand, rocks, fresh water, salt water, etc.

The main advantage of this method is the absence of any interference that could affect the readings of the output values, which might yield more accurate data for the underground water discovery. On other hand, this method requires a huge amount of physical effort to be implemented correctly, and environmental and weather conditions must be considered. For instance, wet land might impact the accuracy of the result obtained.

### *B. Ground Penetrating Radar*

In GPR, the detection algorithm is based on electromagnetic signal transmission over a frequency band. The RF signal is transmitted from a directive antenna toward the targeted location with a specified frequency band and waveform [6]. Then, the reflected signal is collected by a receiver antenna for further processing and analysis in the on-board computer. Previous studies have investigated the technical requirements, field of applications, implementation and operations of GPR [7]. In this study, the focus will be on the underground water discovery application.

A previous study targeted underground aquifers in the south of India using two methods [8], one of which was GPR. The study used both Ultra-High Frequency UHF and Very High Frequency VHF RF signals with repeated short-duration pulses forms. The study clarified that the lower the frequency of the RF signal, the deeper the RF signal can travel; the higher-frequency RF signal could give better resolution for the scanned area, but with lower depth.

Another study, also performed in the southeast of India [9], indicated the performance of GPR in discovering the lower layers of the ground surface. The system was set up in a precise configuration, within frequency band around 40 MHz, with a scanning target of several meters' depth. Two cavities were scanned, and the water stores were found at 20 m and 30 m, respectively. The RF reflected signals from several depth levels: there was significant distortion of the reflected signal below 30 m depth, but the system could estimate the nature of the layer a few meters deeper.

One study also investigated underground water in Brazil [10], with several areas selected for analysis. Two modes were generated for two scanning resolutions. This was based on the propagation speed at which the system was operating, which could reach up to $80\times10^6$ km/s. A 200 MHz antenna was used for transmitting and receiving, with half-wavelength and quarter-wavelength values allowing operation at two different resolutions. This was used to scan the identified piece of land vertically and horizontally. The results showed that the vertical mode detected the water at 2.4 m depth, while the horizontal mode detected the water line at 450 m across the land.

A study implemented in India presented several applications of GPR [11]. This study demonstrated the value of using GPR technology for environmental studies. One of the mentioned studies concerned underground fresh water discovery. This study highlighted some important parameters to be considered during the system design phase. It showed, for instance, that a transmitting and receiving antenna operating at 200 MHz, with 50 scans per meter, could be used to detect water underneath the surface at a depth up to 8 m.

Finally, a study in Russia presented a different way to implement GPR [12]. The GPR model was mounted on a helicopter, with hanged dipole antenna designed for this specific of application. This study allowed the GPR system to operate within a frequency range of 10–50 MHz. The antenna radiation pattern was simulated at 25 MHz. Two experimental field results verified the detection capabilities. The first experiment targeted the ground surface with 25 MHz Tx frequency and successfully penetrated the ground up to 2 m with clear imaging. The second one, with 50 MHz Tx frequency, targeted a leak and successfully reached to 9.4 m depth with clear imaging.

### C. *Interference Synthetic Aperture Radar (INSAR)*

Interferometric synthetic aperture radar (InSAR) is a radar system that transmits a microwave signal from a moving antenna and receives the reflected part of the original signal in such a way as to reconstruct a two-dimensional image of the landscape. InSAR has a wide area of applications, but the scope here is directed towards groundwater investigation and identification. InSAR has a different method for aquifer detection based on ground surface mapping. This is considered an indirect method for underwater detection.

Different studies have been initiated in this field. Some of these examine the vertical deflection of the surface level, which might be a result of the existence of aquifers in the lower layers of the ground [13]. The method of detection is explained in more detail in a previous research study targeting ground water in California [14]. This study used InSAR to discover ground surface deformation caused by neutral ground water, noting that only after filtering all the phase shifts generated by other sources could the surface imaging be maintained by analysing the phase generated by the ground surface.

## IV. RF Interference Study on VHF Operated Radars

### A. *RF Interference*

Microwave signals have always had the potential to overlap with researchers' RF signals travelling in the same shared space. As the use of microwave and wireless systems has become more widespread, this risk has increased. This effect can significantly impact RF passive sensors, which scan the RF environment. To inhibit this effect, the frequency distribution and allocation processes can be implemented, along with global restrictions on high RF power transmitters. This widely recognised global issue is frequently statistically analysed to monitor RF running activities at different frequency bands [15]. This activity helps RF system designers improve the operation of RF transmitters and receivers, which is why a standard has been issued to measure RF frequency [16].

### B. *RF Activities Over VHF Band*

The VHF band covers a frequency range from 30 to 300 MHz, as per the International Telecommunication Union (ITU) standards for global frequency allocation [17]. There are several RF sources operating within this band. Qatar uses the VHF band for several communication applications, including space applications, amateur applications, Private Mobile Radio (PMR), Frequency Modulation (FM) sound broadcasting, air operations and costal operations [18].

### C. *VHF Operations and the Interference with Radar Transmission*

ground VHF operations are implemented in wide area of human applications, all of these systems might be affected by the transmissions of the VHF operated radars, especially when the radar is targeting the ground. Previous study considered some sensitive and military operations sites, operating within the VHF band [19], the effective radiation power which can be considered as significant interference on the ground systems, were measured when radar transmitting at low very low altitude (around 15 m) at transmission of peak power around 10 mW. This proves that the radar transmissions, mainly from those who are placed on very high altitudes, would have ignored interference on the ground system, because of RF path loss.

On the resolution quality side, the electromagnetic interference causes a resolution reduction of the radar, especially those who are operating at VHF and other lower frequency, where they maintain the longer ranges but lower in the resolution quality [20]. A resolution improvement method proposed by controlling the interference has been presented in the paper.

The interference also might be caused by the multi-path propagations. This phenomenon exists in any wireless communication system. The reflections of the transmitted signal is distributed toward several directions of propagations, and it has negative impacts on the transmitter source itself and other operating systems. As the VHF band is widely used, a previous study [21], proposed a precise system which can do better estimation for the angle of arrival of the transmitted signal from the radar toward the target. This helped in reducing the multi-path propagation behaviour in the VHF operated radar.

## V. Experimental Design

### A. *System Design*

The interference survey will be held on the ground surface to allow on-board calibration for the AGSR expected to operate above Qatar. Designing the proper setup will guarantee accurate and valuable data collection. In this study, a passive system will operate to sense, collect and record RF activities around five locations to help understand the interference background in these areas, which are expected to be analysed by AGSR for possible underground water existence. Fig. 2 illustrates the basic configurations.

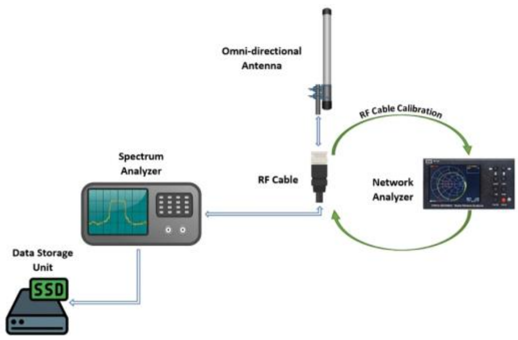


Fig. 2. Deployment configuration

The above deployment consists mainly of two stages. The first will be implemented in the laboratory and will take care of RF cable calibration and losses measurements using the vector network analyser. The second will be implemented onsite and will contain all the setup shown above, but without the need of the network analyser. Further, this second stage will only focus on reading and collecting RF data through the spectrum analyser to the Solid-State Drive (SSD) unit.

## VI. Pre-installation Work

### A. *Definition of Measurements Locations*

A previous study presented the underground water map can be found here [22].

For this research, five experiment locations in Qatar have been identified. Table II shows the coordinates of each location and the justifications for their selections.

TABLE II. COORDINATES FOR THE TARGETED LOCATIONS

| Location Name | Coordinates | Justification for Site Selection |
|---|---|---|
| **North site (zone 5)** | 25.8964387, 51.2486048 | Centred over the northern aquifer |
| **Al Jumayliyah (zone 3)** | 25.637731, 51.0238647 | Groundwater discharge towards west and southwest |
| **Umm Taqa (zone 2)** | 25.2901209, 51.1082692 | Area showing high potentiometric gradients between two distinct hydrogeologic facies (north vs south) |
| **Al Kharrara (zone 1)** | 24.853981, 51.275560 | Mounding and upward leakage |
| **Mazra'at Turayna (zone 4)** | 24.764532, 51.1998762 | Ground water mounding and had shown some very interesting InSAR signal (ground deformation) |

## B. *Proposed System's Configuration*

The main challenge present in the sites is the desert. All the locations are in the middle of the desert, where there is high heat, harsh environment, dust in the surroundings. Therefore, the two configurations have been designed to overcome this challenge and maintain the best configuration for most accurate readings. The first one is the fixed configuration, and the other is the flexible. The details of the two setups are shown in the Table III below.

TABLE III. COMPARISON OF FIXED AND FLEXIBLE SETUPS

| Parameters | Setup A (Fixed) | Setup B (Flexible) |
|---|---|---|
| **Antenna installation** | Fixed on plastic pipes | Mounted on UAV (drone) |
| **Stabilisation** | Antenna fixed with three ropes | Drone auto-stabilisation system |
| **Height** | Fixed height | Variable/controllable height |
| **Safety** | Safe | Risky (drone control loss) |
| **Data scanning continuity** | Continuous | Discontinuous (drone battery to be changed periodically) |
| **Time Consumption** | Long time needed for installation | Short time needed for installation |
| **Connection** | Easy and simple | Complex (RF cable passing between drone rotors) |

A step-by-step installation procedure across the two configurations has been performed to ensure that all the readings were collected under the same conditions, so it will be accepted for fair comparison. Two installation procedures have been generated to achieve the installation shown in Fig. 3.

Fig. 3. Pictures show the fixed & flexible installation setups

## C. *RF Cable Losses Measurments*

The RF cables that transfer the carrier signal between the antenna and receiver/transmitter. The signal losses, measured in dB can be determined using the network analyser. In this study, the antenna will be receiving a VHF signal, and passing it to the spectrum analyser. The network analyser is connected to a 5 m RF cable, where the cable losses over VHF band can be measured. Fig. 4 shows the result.

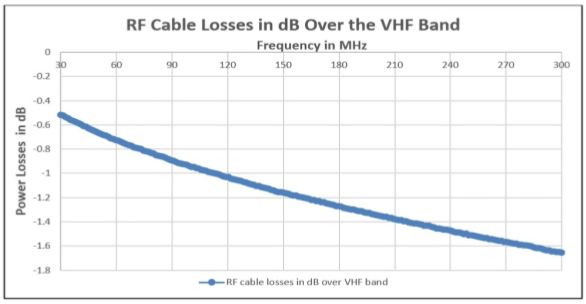


Fig. 4. RF losses in the RF cable verses operating frequency

Fig.4 shows that losses increase as frequency increases. The relationship between the losses and the frequency is not linear, which means that the losses effect will be greater at higher frequencies. This measurement should be combined with the RF results of all the experiments employing this cable. However, when the whole VHF band, has losses factor around 1.2 dB only, and when smaller piece of the VHF band at 50 MHz span only is tested, with losses factor less than 0.25 dB. It is possible to say the RF cable is almost operate with no losses during the experiments.

# VII. PRE-INSTALLATION WORK

## A. *Varification Experiment*

The proposed two setups previously presented in Fig. 3 will be verified and confirmed as eligible to scan the RF activities in the five locations. Implementation of both setups for verifying the operational performance is critical to ensuring the quality of the data.

*1) Fixed Setup Verfication*: The same configuration shown in Fig.3 was implemented and began receiving from 20 to 275 MHz (a bandwidth covering the studied bandwidth). The result was expected for this bandwidth, and a flat line of noise between 150 and 200 MHz is confirmed, as shown below.

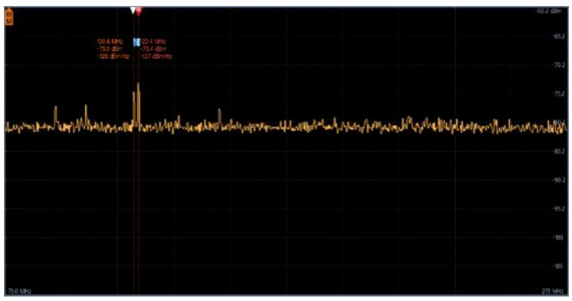

Fig. 5. RF output reading from fixed setup

In Fig. 5, only a few signals appear in the low frequencies, some of which represent FM band. The band from 150–200 MHz does not show any significant activities.

*2) Flexible Setup Verification*: The flexible setup required less time in the installation and preparation phase, and the antenna mounted on the drone as shown in Fig. 4, and the spectrum had the same setting used in the previous verification test. Fig. 6 and Fig. 7 show the results.

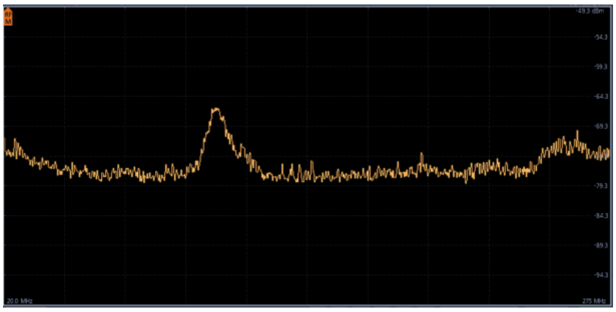

Fig. 6. Noise generated from the drone within the studied band - drone on the land

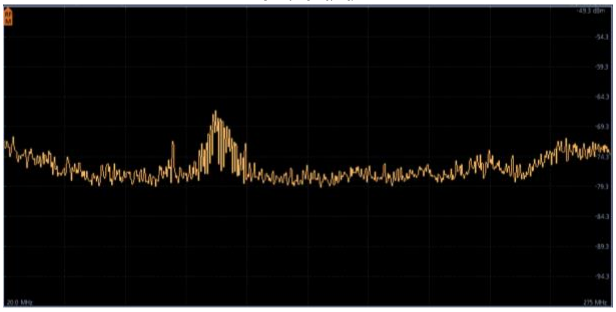

Fig. 7. Noise generated from the drone within the studied band - drone during flying.

As shown in Fig. 6 and 7, when the drone switched on, the spectrum readings had changed and RF power increased within the band being scanned. Within the 150–200 MHz, there are some RF peaks, showing that there were RF interference caused by drone. Although the drone took off and reached a height of 5 m above the ground level, the noise was still detectable, as shown in Fig. 7. This result is concerning, as it has a direct impact on the RF readings. The source of the generated signals on the spectrum analyser is not yet identified, but more investigations can be done to help avoid or filter these noises.

### *B. Verification Experiment Result*

The data collected from the verification experiments confirm that the best setup for this research is the fixed setup, which will be implemented in all the measurements' locations, this was confirmed after noticing the noise generated from drone within the obseved band.

### *C. Physical Characteristic & Related Enviromental Parameters for the Sites*

Each RF sensing experiment site has some characteristics that directly or indirectly impact RF propagation. Each site has been analysed from a different perspective, including the occupancy of the area around the site, the presence of physical buildings or natural obstacles, and height above sea level. table IV defines these physical properties and characteristics.

TABLE IV. PHYSICAL PROPERTIES & CHARACTERISTICS IN EACH SITE

| Location Name | Physical Properties and Characteristics |
|---|---|
| North site (zone 5) | ➢ Site is 21 m above sea level.<br>➢ The site was surrounded by many wide green areas (private farms).<br>➢ Ras Laffan oil and gas industrial city is 15 km to the east; heavy operations take place there, in addition to military sea operations.<br>➢ The site land is flat, mixed with sand and rocks. |
| Al Jumayliyah (zone 3) | ➢ Site is 17 m above sea level.<br>➢ Sea line is 4.5 km to the west.<br>➢ No RF sources have been noticed in the surrounding area of the site.<br>➢ Several green desert trees were in the sites, with sand mixed with rocks on the land.<br>➢ The nearest village is 5.5 km to the east. |
| Umm Taqa (zone 2) | ➢ Site is 33 m above sea level.<br>➢ Western area of the site has some animal farms.<br>➢ GSM tower is 1 km away (line of sight).<br>➢ Military operations on eastern area of the site.<br>➢ The site land is mixed sandy and rocky land. |
| Al Kharrara (zone 1) | ➢ Site is 29 m above sea level.<br>➢ The site is at the lowest point of the area, taking the shape of a hole in the middle of the desert.<br>➢ Large green farm is <1 km to the northwest.<br>➢ A GSM tower is 1 km east.<br>➢ Several small sand mountains were distributed south of the site.<br>➢ The site land is very rocky, with different rock sizes. |
| Mazra'at Turayna (zone 4) | ➢ Site is 50 m above sea level.<br>➢ The installation point was the highest point in the area.<br>➢ GSM tower and dipole antenna tower were 1.1 km to the west.<br>➢ The area has several green desert trees around, all below the site level.<br>➢ A green farm is 1 km to the southeast. |

Additionally, as the RF propagations in general is getting affected by surrounding environmental and weather parameters, such as field temperature, air humidity, clouds and other parameters [23, 24], the weather temperature, air humidity and wind speed on the day and at the time of the site visit are recorded in table V.

TABLE V. WEATHER PARAMETERS & MEASUREMENTS TIMING

| Site Name | Measurements Collection Date | Measurements Collection Time | Weather Temperature | Air Humidity (%) | Wind Speed (km/h) |
|---|---|---|---|---|---|
| North site (zone 5) | 8 Oct 2022 | 8:00 AM to 11:30 AM | 32 to 34 ºC | 59 to 71 | 11 to 17 |
| Al Jumayliyah (zone 3) | 15 Oct 2022 | 8:00 AM to 11:30 AM | 32 to 33 ºC | 56 to 63 | 13 to 19 |
| Umm Taqa (zone 2) | 1 Oct 2022 | 8:00 AM to 11:30 AM | 31 to 36 ºC | 32 to 66 | 9 to 11 |
| Al Kharrara (zone 1) | 22 Oct 2022 | 8:00 AM to 11:30 AM | 30 to 36 ºC | 28 to 70 | 9 to 11 |
| Mazra'at Turayna (zone 4) | 29 Oct 2022 | 8:00 AM to 11:30 AM | 28 to 35 ºC | 20 to 74 | 6 to 9 |

### *D. Results Sammary*

Table VI below shows all the details of the spectrum readings recorded in the five sites. All the values or parameters in the table have been extracted from the spectrum analyser and stored in .csv form, and all the data were verified.

TABLE VI.

RESULTS OF THE SPECTRUM SCANNING IN THE FIVE LOCATIONS (USING THE FIXED INSTALLATION)AT EACH SITE

| Site Name | Scanned Span (MHz) | Spectrum Average Power (dBm) | Reading Scale | Scanning Mode | Peak Value (dBm) |
|---|---|---|---|---|---|
| North site (zone 5) | 50 (150 to 200) | -87.1 | 5 dBm/div | Maximum hold | -84.4 |
| Al Jumayliyah (zone 3) | 50 (150 to 200) | -87.3 | 5 dBm/div | Maximum hold | -85.4 |
| Umm Taqa (zone 2) | 50 (150 to 200) | -84.6 | 5 dBm/div | Maximum hold | -81.7 |
| Al Kharrara (zone 1) | 50 (150 to 200) | -87.3 | 5 dBm/div | Maximum hold | -85.2 |
| Mazra'at Turayna (zone 4) | 50 (150 to 200) | -84.6 | 5 dBm/div | Maximum hold | -81.8 |

## VIII. CONCLUSION

The underground accumulations are considered a national water resource in Qatar. This research aimed to read and present RF activities within VHF band in five locations in

Qatar. The results of this research will be reflected in the AGSR model design for underground water discovery. The implementation of the ISM, based on the design requirements of the AGSR model, ensured the same installation process in each site and followed the recognised standards set by international institutes in RF field operations. This helped in obtaining the results, which will be valuable input to the AGSR's onboard antenna, transmitter and receiver. None of the five sites showed significant operations within the band from 150 to 200 MHz. The highest noise level was found in the site 'Umm Taqa', located in the middle of Qatar. The detailed spectrum readings of the frequency span (150–200 MHz) divided the spectrum into 10 divisions, aiming to help the AGSR designer to find the lowest noise slots and implement this information in the onboard transmitter and receiver.


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