International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

RF Propagation Model for Wireless Sensor Network of MARs

Nilofar A. Shekh, Ved Vyas Dviwedi, Jayesh P. Pabari

Abstract: ***NASA exploration mission on Mars includes the use of rovers and sensors communicating via wireless sensor networks. The network components have a limited range of transmission, low power consumption, low price and a small lifespan. A wireless network's performance is mainly dependent on the RF environment. A Wireless Sensor Network (WSN) on the Mars ground is planned to deploy wireless sensors capable of operating under harsh environmental conditions to detect few properties of regolith on the Martian surface. The main interest property is dielectric permittivity and permeability. Since communicating on the Mars is a difficult and challenging task, the behavior of communications surfaces can be predicted by a channel model. So, efforts have been put to Develop a channel propagation Model to know the behavior of communication channel on the atmosphere of Mars. In order to study the model for radio propagation on Mars, two sites were selected from Gale crater and Meridian Planum at different sites for the Mars with near-flat surfaces, a certain area with peaks and a region with few craters.***

Keywords: Hematite, Mars, Site Coverage, Wireless model

I. INTRODUCTION AND MOTIVATION

In wireless communication systems the signal waves travel among the transmitterand receiver through a wireless channel which is the basic part of the wireless system. There are many factors affecting the propagation of the wireless signals in any environment. It can be interference, obstacles, refraction like buildings, trees, mountains, sand particles etc. All these constraints highly effect the radio wave transmitting data. The RF propagation model is defined as a mathematical formulation which is empirical type. Its purpose is to know the pattern of propagations in a given frequency, distance and some other conditions. Its help to find out how much the transmitted radio signal is going to be affected. This predicts the path loss when a radio wave will pass through a link under specific constraints. Forthisreason,engineersdevelopedpropagationmodelstoexpectthestrength of the signalatthereceiver.The RF propagation models are the essential tool to design wireless communication systems for all applications. NASA exploration mission on Mars includes the use of sensors and rovers communicating via wireless sensor networks. The network components have a limitedrange oftransmission, low power consumption, low price and a small lifespan. A wireless network's performance is mainly dependent on the RF environment [1]. The Wireless Sensor Network is prepared to deploy on the Mars surface that capable of operating under harsh environmental conditions to detect some soil properties i.e. hematite on the Martian surface. The main interest of properties are dielectric permittivity and permeability. Since communicating on the Mars is a difficult and challenging task, the behavior of communications surfaces can be predicted by a channel model. Various models for radio communication have been implemented on Earth, such as a Longley Rice model also identified as the Irregular Terrain Model (ITM)[2]. For terrestrial communication network, ITM is a one of the bestmodels. J.F. wagan and E. lachat explained the ITU model for multi-knife-edge diffraction.Hata method uses mathematical equations involving transmitter and receiver antenna heights, frequency from 150MHz to 1500MHz [3]. Bertoni and Walfisch Provided a model to understand rooftop effect and building height by using diffraction to estimate the average street - level the strength of the signal [4]. S. Willis andC.J. Kikkertdiscuss the fundamental radio propagation principles and propose a new model for radio propagation of wireless networks with high-range sensors[5]. Chukkala et al provided simulation of the Mars Radio Frequency (RF) environment[1]. Pabari et al. explain the new radio propagation model for the moon[6].

The operating frequency is 2.4 GHz in the present application scenario, and deployment of sensor on the surface of Mars, where functioning conditions differ from those on Earth. It's known that there's a very thin atmosphere on Mars. The models of communication intended for earth communication networks do not apply directly to the space surface, as expected on the Mars, and require changes according to the atmosphere and surface terrain of the Mars. This inspired us to carry out the work described in this report. So, to derive the radio frequency model on the Mars with simple formulas governing different physical processes that arise during radio propagation. Mars' largest global data collection is from the MOLA (Mars Orbiter Laser Altimeter) that was part of that Mars Global Surveyor mission in 1999. The work uses data sets from two Mars sites using the Mars Orbiter Laser Altimeter (MOLA).

Revised Manuscript Received on December 30, 2019.

* Correspondence Author
Nilofar A. Shekh*, Assistant Professor, Department of Electronics and Communication Engineer, Sardar Vallabhbhai Patel Institute of Technology, Vasad-Anand-Gujarat, India.
Dr. Vedvyas Dwivedi, Department of Electronics and Communication, Birla Institute Of Technology Jharkhand, India.
Dr. Jayesh P. Pabari, Lecturer, Department of Electronics Engineering, R.D. College, Jabalpur, India.

II. EXISTING PROPAGATION MODEL SUITABILITY FOR MARS APPLICATION:

Because of the very thin atmosphere on the Mars, the communication is expected to be better on the Mars than on the Earth. Few current propagation models have been developed for communication on the Earth and in view of their applicability, it is necessary to examine for the Mars.

A. Free Space Loss

The power radiated through an antenna is evenly spread over the surface of an imaginary sphere neighboring the antenna in an ideal atmosphere. Therefore, the power density decreases as the distance from the antenna increases. at the point on the sphere. The equation of free-space loss (1) gives the power received from the antenna at a given distance[7]. The objective is to make use of the line of sight propagation techniques up to a few hundred meters for small distances. Under ideal communication conditions, in the horizontal plane of interest here, the power radiated from the omni-directional antenna and power received of free space is specified by Friis equation

$$P_r = \frac{P_t G_t G_r \lambda^2}{16\pi^2 d^2} (1)$$

Here P_t is power of the transmitter and P_r is power of the receiver, G_t is the gain of transmitter antenna and G_r is the gain of the receiver antennas, λ is operating wavelength and d is the distance from the transmitter. The loss occurred due to the Free space is a fundamental loss to communicate on the Mars surface as there is a very thin atmosphere compared to earth on the Mars.

B. Reflection

Reflection occurs on large specular surfaces when a signal is transmitted. The transmitted signal reflections enable the receiver to receive multiple signals. This phenomenon is known as multipath propagation. Each signal reaching the receiver will have varying amplitude and phase and the resulting signal can be enhanced or diminished. Factors such as steady and moving reflectors and scatterers, atmospheric absorption etc. may occur for communication on Earth and get result in multipath components on the receiver. The strength of the signal can differ at the receiver because of moving scatterers due to multipath components. Moreover, in the case of Mars application, no objects are there in motion on the Mars surface and thus, due to surface topography, multipath signals may occur at the receiver, but strength of the received signal is not probable to change arbitrarily because of steady terrain, but it may show the periodic signals variations traveling over different time durations. On Mars the atmosphere is very thin [7] and thus, the atmospheric losses that are present in earth are negligible. Due to the rough terrain composition, surface reflections are the main possibility of the signal being affected. This can induce the multipath propagation, and due to multipath elements, the signal arriving at the receiver will be changed by direct path. There are few expected multipath components as the lander of the mission must land on a moderately flat or smooth surface where the rover is easy to move. The wavelength of the signal is 12.5 cm at frequency 2.4 GHz wireless transmission and objects should be larger for reflection. The signal strength obtained using the coefficient of reflection Γ given below [7].

$$Pr = \frac{P_t G_t G_r \lambda^2}{16\pi^2 d^2} .| 1 + \Gamma \, exp(j\Delta)|^2 \quad (2)$$

Where $\Gamma = \frac{a.\sin\psi - \sqrt{(\varepsilon r - jx) - cos^2\psi}}{a.\sin\psi + \sqrt{(\varepsilon r - jx) - cos^2\psi}}$

is coefficient of reflection

Δ= reflected signal phase shift

a = 1 or for horizontal or vertical polarization correspondingly

ψ = incidence angle between vertical from the transmitter antenna to the reflector

ε_r= relative permittivity of the surface

$$x = \frac{\sigma}{2\pi f \varepsilon_0}$$

σ = ground conductivity

f= operation frequency

ε_0= free space permittivity

A wave can be reflected from the earth's surface in several applications, which can lead to a significant cancelation by a direct wave on the receiver., and therefore to a loss in strength of signal. The strength of the received signal can be determined using the Plane-Earth Model (3), as explained in[8]. This calculation is based on a two-ray model with low antenna elevations for long links.

$$P_r = \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4} \quad (3)$$

whereh_t is the height of the transmitter antennas and$h_r$is the height of the receiverantenna. From nearby ground terrain on the Mars reflections are expected. In addition, a multipath formed by reflection from craters and surface irregularities is the main component of channel fading on the Mars. Additionally, for ground sensors the transceiver uses horizontal polarization; if not the signal may be attenuated very close to the transmitter. Alternatively, it is important to use vertical polarization, which at far distances can provide a sufficient signal.

C. Reflection Scattering

where $\theta_i$is the incidence angle and the parameter $h$which is the minimum to maximum deviation of average terrain height[9]. When the surface is considered smooth its minimum to maximum protuberance h is smaller than h_c, and assumed is rough if the protuberance h is larger than h_c. For rough surfaces, the scattering loss factor ρ_S needs to be multiplied by the flat surface reflection coefficient. This loss factor is determined by the formula of Bothias.

$$\rho_s = \exp\left[-8\left(\frac{\pi\sigma_h cos\theta_i}{\lambda}\right)^2\right] I_0\left[-8\left(\frac{\pi\sigma_h cos\theta_i}{\lambda}\right)^2\right] \quad (5)$$

where $\sigma_h$is the standard deviation of surface height for the average surface height and$I_0$is the first kind of 0th order Bessel function. On the surface of Mars, the areas are typically rugged and it may have a terrain of variable size, which may result in losses of scattering.

D. Diffraction Loss:

Diffraction happens when an obstacle that is greater than the wavelength of the signal blocks the direct line between the transmitter and receiver. The signal is scattered by the obstacle's edges and attenuated when the target is in the obstacle's shadow. The knife edge diffraction can cause the signal to bend behind the obstacle. It is also worth noting that the bending of the signal allows the signal strength behind a knife-edge obstacle to be considerably greater than that behind a rounded obstacle[10]. For line of sight communication, a loss of diffraction on the edge of an obstacle can occur if an obstacle of wavelength comparable to the transmitter or receiver is present. Upon entering the receiver, the signal can be dispersed and attenuated. Diffraction from the knife edge obstacle will cause signal bending and signal bending because of knife edge obstacle resulting in more strength of the signal than rounding [10]. On the terrain of the Martian, these barriers are likely to be considered between the transmitter and the receiver. Because of the presence of a knife edge, the diffraction gain is represented by,

$$G_d(db) = 20 \log |F(v)|$$

The Fresnel integral, F(v), depends on the diffraction parameter v of the Fresnel Kirchoff.

$$v = h\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2)}} \qquad (6)$$

Where h is the effective height with infinite width be placed between them at a distance d_1 and distance d_2. d_1 is the distance from the transmitter and d_2 is the distance from the receiver.

III. MARS WIRELESS MODEL

In this wireless Mars model taken loss due to free space, loss occurs due to reflection, scattering loss and knife edge diffraction. The loss due to the Mars refraction is negligible [11], thus the effective radius of Mars is equal to its physical radius. So, refraction loss of Mars is negligible here.

The following mathematical model is given for RF propagation for Multipath and it’s also gives the area coverage of the wireless sensor network on the Mars surface:

$$P_r = \frac{P_tG_tG_r\lambda^2}{16\pi^2}\Big|F(v_1)\rho_{s1}\Gamma_1(\Phi_1)\frac{1}{d_1}\exp(-jkd_1) + F(v_2)\rho_{s2}\,\Gamma_2(\Phi_2)\frac{1}{d_2}\exp(-jkd_2) + F(v_3)\,\rho_{s3}\,\Gamma_3(\Phi_3)\frac{1}{d_3}\exp(-jkd_3) + \ldots\ldots\ldots\ldots + F(v_n)\,\rho_{sn}\Gamma_n(\Phi_n)\frac{1}{d_n}exp(-jkd_n)\Big|^2 \qquad (7)$$

where $F(v_n)$the Fresnel integral is a Fresnel diffraction function, $\Gamma_n(\Phi_n)$is the nth ray reflection loss ofthewhich has an incidence angle Φ_n. The delay determines the phase of each ray and is represented by the component exp(-jkdn), Where d_n is the distance traveled by the nth ray and $\rho_{sn}$is reflection scattering loss factor of nth multipath. This corresponds to the sum of the transmitter and receiver distances from the reflector. The incidence angle is selected at the Brewster angle and the reflector location is determined to allow the reflection to enter the receiver for the given incidence angle. The reflectioncoefficient dielectric constant is of the soil on the Martian planet measured by the wireless dielectric sensor.

Here considered smaller number of multipath. The number of multipath can calculate using given formula in (8) as given in [12]:

$$N = 1 + 2BW\tau \qquad (8)$$

$$\tau = \frac{\Delta}{c}$$

$$\Delta = \frac{2\,h_th_r}{d}$$

Where h_t is the transmitter height , h_r is the receiver height and the distance from the transmitter and receiver is d.

IV. MARS DIGITAL ELEVATION MAP

The development of RF propagation model for planetary surface, in particular of the RF coverage pattern, must have a high resolution DEM at sites of interest. The largest global data collection on Mars comes from the Mars Orbiter Laser Altimeter (MOLA), part of the Mars Global Surveyor mission in 1999[13]. The HiRISE images taken by Mars are large and powerful and HIRISE pictures covering huge areas of Martian land while showing features as low as a kitchen table[14].A maximum spatial resolution of the data set has 128 pixels / degrees, or about 400 m / pixel.

V. DESCRIPTION OF SELECTED SITES

In order to study the model for radio propagation in Mars, two samples were selected at different sites on the Mars with near-flat surfaces, a certain area with peaks and a region with few craters. The Mars ScienceLaboratory (MSL) rover Curiosity has completed recently its fourth Mars sediment sampling drill. The samples from the Confidence Hills (CH) were taken from a rock found at the base of Mount Sharp in Gale Crater in the Pahrump Hills area. Five nights of sample analysis were more complete than previously done for a sample of drills by the CheMin X-ray diffractometers and data was analyzed by means of Rietveld refining and full sample fitting for a quantitative mineralogy. The mineralogy of gale craters is rich in hematite and less magnetite[15].The discovery of the signature of a large quantity of Hematite from the Orbit of the Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES), was one of the most important discoveries at the landing site in the Meridiani Planum at the Mars Exploration Rover[16].That’s why the Endeavor Meridiani crater site and the Gale crater site were chosen for implementation. Quite exceptional in its orbital signature is the Meridiani Planum; the MGS Thermal Emission Spectrometer has shown the highest, most detailed significance of any field on the planet for crystalline hematite. Due to the fact that the modes of hematite(Fe_2O_3) development contain liquid water, Meridiani Planum is the prime place to explore. [17].

The Mars Research Laboratory (MSL) rover Curiosity landed near the Martian hemispheric dichotomy in Gale Crater, about 155 km in diameter, in August 2012. Gale Crater was chosen as the landing site because of the size of the ~5 km high mound of layered rock in its middle-called Mount Sharp. Hyperspectral data collected on the Compact Reconnaissance Imaging Spectrometer (CRISM), Mars Reconnaissance Orbiter (MRO), show that the Mount Sharp consists of a stratigraphic sequence of Fe-Mg Smectites, at its lowest level.

Curiosity found clay and Fe oxides in fine-grained sediments along the traverse to Hematite Ridge after landing in August 2012[18].The first site in figure 1-(a) is at between the flat crater and the second site in 1-(b) area with a number of small craters .Table 1 displays the co-ordinates for the two locations used in the RF simulation.

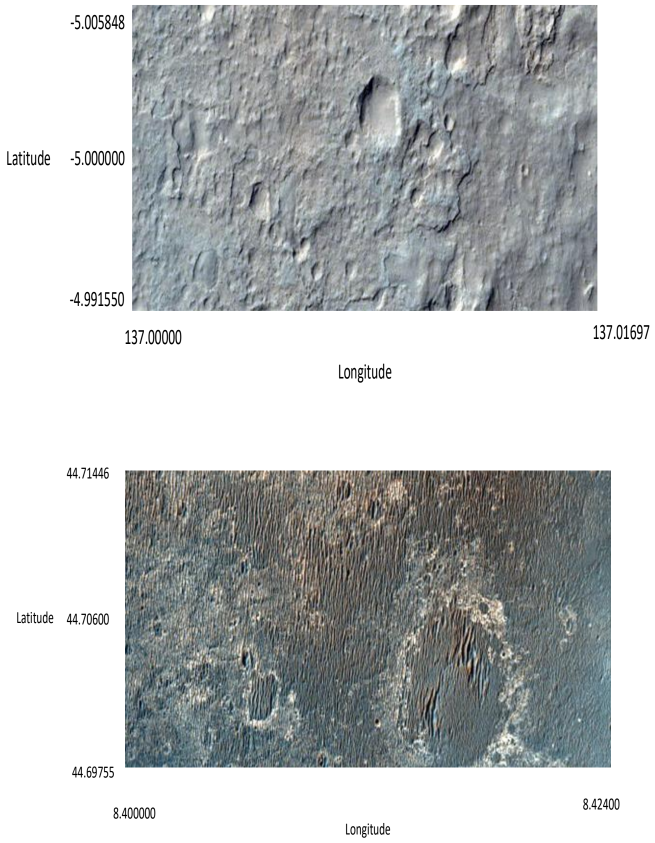

Figure 1 (a) Mars site1 (b) Mars site2

Table 1: Mars selected sites for RF model

Site Number	Site Name of Mars	Mars Latitude	Mars Longitude
1	Meridian Planum	44.69755 to 44.71446	8.400 to 8.424
2	Gale Crater	-4.99155 to -5.00848	137.00 to 137.01697

VI. SITE COVERAGE

Radio coverage of sites is defined as areas where RF power is -97 dbm to the total coverage area of site region. For both the sites, the total coverage area is a 1000m × 1000m rhombus. Radio coverage of site 1 is 30.854% and radio coverage of site 2 is 6.21%. Site 1 was chosen with a relatively flat surface with minor undulations on the bottom, whereas site 2 has craters. Because of this, site coverage is, as predicted, much smaller for sites 2 than for sites 1. From the RF coverage of selected sites on Mars, for example, a region receiving more than -97 dBm power can be identified areas with more than a certain specific value of the power received. Results show the percentage coverage of a certain site with known topography and the option to test whether a certain sensor node is useful on the Mars for energy.

Table 1Site coverage

Site number	Coverage area of sites (250 kbpslink)
1	30.854%
2	6%

VII. RESULTS AND DISCUSSION:

In (7) which assume that all feasible phenomenon and losses in the wireless sensor network on the Mars, the Mars wireless model is given. For simulation of this model MATLAB code was generated and MOLA data were considered from the process input along with the values shown in Table 3 and the results are shown in Figures 2(a) and (b) respectively.

Table 1 Input parameters for RF Model of Mars

Parameters of model	Value
Frequency	2.4 GHz
Transmitter Power	0 dbm
Polarization	Vertical
Type of Transmitter Antenna	Microstrip Antenna
Type of Receiver Antenna	Microstrip Antenna
Transmitter Location	Middle Left
Permittivity	4
Conductivity	1.0 X 10^{-8} s/m

Here the number of components in multipath can be reduced to limited numbers, which is justified reasonably because mars is covered by a large number of terrain and if we consider all multipath then the complexity of the code is increased. In fact, it requires highly sophisticated computational equipment and computation takes a long time. Normally, sensor node operates in 2.4 GHz and here input power is 0 dBm receiver sensitivity is about -97 dBm [19]. For both the sites, the total region is a 1000m × 1000m rhombus taken.

As shown in Table 3 the radio coverage percentage on all sites for the 250 kbps link and shows an effective region for sensor deployment. Figure (a) and (b) shows the longitude, latitude versus received power for site 1 and site2 according to site coverage region.

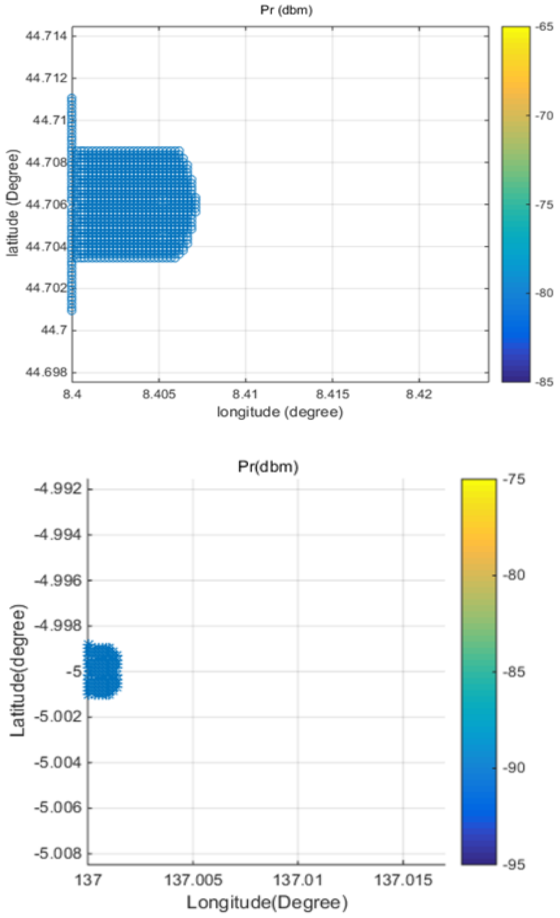

Figure 2 RF channel Model (a) Site 1(b) Site 2

VIII. CONCLUSION

RF propagation model has been developed and the multipath environment at selected locations on Mars was modeled by the use of actual field data. We examined that current models of radio frequencies could not be applied directly to the Mars Wireless sensor network and wireless model MARS from essential physical phenomena that occur through the propagation of the Mars wave. By using real Mars data from MOLA, we provided radio signals from two Martian sites. We used 0 dBm transmitter power for transmitter and receiver at 2.4 GHz.frequency with Microstrip antennas. The results show percentage coverage on the surface of the Mars for 250 kbps connections, proposes the use of commonly available transceivers of sensor node and selected deployment sites and rover paths and ensure wireless connectivity.

REFERENCES

1. V. Chukkala and P. De Leon, “Simulation and analysis of the multipath environment of Mars,” IEEE Aerosp. Conf. Proc., vol. 2005, pp. 1–6, 2005.
2. G. a Hufford, a G. Longley, and W. a Kissick, “A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode,” 1982.
3. M. Hata, “Empirical Formula for Propagation Loss in Land Mobile Radio Services,” IEEE Trans. Veh. Technol., vol. 29, no. 3, pp. 317–325, 1980.
4. H. L. B. J. Walfisch, “A theoretical Model of UHF Propogation in Urban Environments.” pp. 1788–1796, 1988.
5. S. L. Willis and C. J. Kikkert, “Radio propagation model for long-range ad hoc wireless sensor network,” 2005 Int. Conf. Wirel. Networks, Commun. Mob. Comput., vol. 1, pp. 826–838, 2005.
6. J. P. Pabari, Y. B. Acharya, U. B. Desai, S. N. Merchant, and B. Gopala Krishna, “Radio Frequency Modelling for Future Wireless Sensor Network on Surface of the Moon,” Int. J. Commun. Netw. Syst. Sci., vol. 03, no. 04, pp. 395–401, 2010.
7. T.S. Rappaport, Wireless communications. 2002.
8. [J. M. Hernando and F. Perez-Fontan, Introduction to Mobile Communications Engineering. 1999.
9. J. D. Gibson, The Communications Hand book, vol. 23, no. 3. 2013.
10. A. H. K. Wong, “Field Strength Prediction in Irregular Terrain – the PTP Model,” Sci. York, pp. 1–8, 2002.
11. V. Chukkala, P. De Leon, S. Horan, and V. Velusamy, “Modeling the radio frequency environment of Mars for future wireless, networked rovers and sensor webs,” IEEE Aerosp. Conf. Proc., vol. 2, pp. 1329–1335, 2004.
12. M. P. Profiles, M. Pätzold, S. Member, A. Szczepanski, and N. Youssef, “Methods for Modeling of Specified and Measured,” vol. 51, no. 5, pp. 978–988, 2002.
13. S. D. Smith, G. Neumann, R. Arvidson, E. Guinness and Slavney, “Mars global surveyor laser altimeter mission experiment gridded data record, NASA Planetary Data System (MGS-M-MOLA-MEGDR-L3-V1.0),” 2003.
14. “Science - NASA Mars.” [Online]. Available: https://mars.nasa.gov/mars2020/mission/science/.
15. P. D. Cavanagh et al., “Confidence Hills Mineralogy and CheMin Results from Base of Mt. Sharp, Pahrump Hills, Gale Crater, Mars,” 46th Lunar Planet. Sci. Conf., no. Abstract 2735, pp. 4–6, 2015.
16. W. M. Calvin et al., “Hematite spherules at Meridiani: Results from MI, Mini-TES, and Pancam,” J. Geophys. Res. E Planets, vol. 113, no. 12, p. 1 to 27, 2008.
17. L. A. Soderblom et al., “Soils of eagle crater and Meridiani Planum at the opportunity Rover landing site,” Science (80-.)., vol. 306, no. 5702, pp. 1723–1726, 2004.
18. A. A. Fraeman et al., “A hematite-bearing layer in gale crater, mars: Mapping and implications for past aqueous conditions,” Geology, vol. 41, no. 10, pp. 1103–1106, 2013.
19. Datasheet, “CC2530F32 , CC2530F64,” no. February, 2011.

AUTHORS PROFILE

Nilofar A. Shekh, has been awarded the B.E. (2004) and M.E. (2006) degree in Electronics from M S University, Vadodara-Gujarat. She is pursuing a Ph.D. from the C U ShahUniversity. She is working as an Assistant Professor in Electronics and Communication Eng. Department of Sardar Vallabhbhai Patel Institute of Technology, Vasad-Anand-Gujarat since 2006. Her major research interests are in Embedded system, networking and Wireless sensor Network. She has published 7 journal and 3 conference papers.

Dr. Vedvyas Dwivedi, has been awarded the M.E. degree in Electronics and communication from Birla Institute of TechnologyJharkhand in 2004 and Ph. D. from Singhania University Jhunjhunu, Rajasthan. He has 24 years of experience (4.5 years industry plus 19 years 8 months in higher education for teaching, research, management and governance). He has guided PhD, MTech, B.Tech. EC Eng. He has guided 09 Ph.D.(awarded), 4 M. Phil awarded, 34 M Tech awarded. He has completed 12 research consultancy projects including ISRO, 8 patents published, 1 patent under review, 14 Books (7 internationals, 7 national) authored. He has examined 4 US PhD thesis and 17 Indian Ph.D. thesis, 2 post doctorate fellows pursuing. He has delivered 41 key note talks in various countries like Malaysia, China, Japan, Russia and at institutions namely: IIM Ahmedabad IIT Kharagpur, Pune University, IIT-BHU, Patanjali University, S.P. University, Pacific University, GTU, JNTU. CHARUSAT, DDU. Amaravati University, Symbiosis University. He has Worked in various capacities as HoD, Academic council, Board of Studies, Governing body, Board of Management, Research Council, Board of Examiners, Recruitment and Selection Committees, Post-Doctoral Program Reviewer at NASA Advisory since 2017.His google scholar citation 2136, h-index is 17, i10 index is 25 60 Scopus papers, Scopus index 7.

Dr. Jayesh P. Pabari, has been awarded his Master degree (M.E.) in communication system from R.D. College, Jabalpur, India, and Ph.D. From the IIT, Mumbai, 2011. He was a lecturer at the Nirma Institute of Technology at Department of Electronics Engineering, Ahmedabad, India, for about three years. He has worked with the Physical Research Laboratory, Ahmedabad, as electronics engineer for over ten years and has also been affiliated as a researcher with the Department of Electrical Engineering, IIT Bombay, India.His main Interests in research are the development of sensors, wireless communication, spectroscopy of impedance and signal processing. He is currently involved in research activities in the area of planetary science applications. He's a reviewer for some reputable international journals.Mr. Pabari is a member of the Institution of Electronics and Telecommunication Engineers (IETE) and of The Institution of Engineers (India).