International Journal on Advanced Science Engineering Information Technology

Vol.6 (2016) No. 5
ISSN: 2088-5334

Temperature Effect on The Tropospheric Radio Signal Strength for UHF Band at Terengganu, Malaysia

Roshidah Mat[#], Marhamah Mohd Shafie[*], Sabri Ahmad[#], Roslan Umar[*], Yew Been Seok[#], Nor Hazmin Sabri[#]

[#]*School of Fundamental Science, Universiti Malaysia Terengganu, Terengganu, 21030, Malaysia*
E-mail: roshidah@ipgmksm.edu.my, norhazmin@umt.edu.my

**East Coast Environmental Research Institute, Universiti Sultan Zainal Abidin, Gong Badak Campus, Gong Badak, Kuala Nerus, Terengganu, 21300, Malaysia*
E-mail: marhamah92@yahoo.com, roslan@unisza.edu.my

[#]*School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu, Terengganu, 21030, Malaysia*
E-mail: sba@umt.edu.my

[#]*Faculty of Innovative Design and Technology, Universiti Sultan Zainal Abidin,Kampus Gong Badak, Terengganu, 21300, Malaysia*
E-mail: bseokyew@unisza.edu.my

***Abstract*— In tropospheric layer, radio waves can propagate in a number of different physical mechanisms such as free-space propagation or line-of-sight propagation, reflection, transmission, diffraction, scattering and wave guiding. The constituents in weather such as the wind, air temperature and atmospheric water content may combine in many ways. Certain combinations can cause radio signals to be heard hundreds of miles beyond the ordinary range of radio communications. This study investigates the effect of weather (temperature) on radio wave propagation up to 9GHz. Continuous-wave (CW) envelope fading waveforms were recorded over a period of the one-hour using patch antenna. The observations were conducted at KUSZA Observatory, East Coast Environmental Research Institute (ESERI), UniSZA which is situated in Merang, Terengganu. Spectrum Analyser was used for RFI measurement and weather station for weather effect. The graphs of radio signal attenuation for weather parameter (temperature) against time were plotted. The findings indicate that there is a relationship between radio signals with the change of temperature. The correlation between RFI frequencies and temperature give negative effect for frequency 945 MHz, was r = -0.085, while for 383 MHz (r = 0.249), 1800 MHz (r = 0.268) and 2160 MHz (r = 0.134). These findings will benefit radio wave propagation research field which includes radio astronomy observations, space science, wireless communication, satellite, antenna and mobile communication and also electromagnetic radiation (EMR) research for health.**

***Keywords*— temperature effect, radio signal propagation, radio astronomy, radio frequency interference.**

I. INTRODUCTION

A radio wave is one of the seven components in Electromagnetic Spectrum (EM). It can be classified into twelve frequencies range called bands. They are Ultra low frequency (ULF), Very low frequency (VLF), very high frequency (VHF), ultra high frequency (UHF) and many more. Radio spectrum has the longest wavelengths and lowest frequencies of all the electromagnetic waves. The wavelength ranges from $1x10^{-2}$ m to $1x10^{5}$ m whereas the frequencies may be as low as 3 kHz or as high as $3x10^{3}$ GHz [1]. They can move around obstacles and used in radio communication and television transmission over long distances. Most of the radio transmissions are carried out in the lower layers of the atmosphere, near the surface of the earth which is called troposphere. In this layer, radio waves can propagate in a number of different physical mechanisms such as free-space propagation or line-of-sight propagation, reflection, transmission, diffraction, scattering and wave guiding [2]. The difference of these propagation mechanisms can enable radio signals to reach their destinations. Weather changes normally take place within troposphere layer, which affected most of the terrestrial radio propagation. The constituents in weather such as the wind, air temperature and atmospheric water content may combine in many ways. Certain combinations can cause radio signals to be heard hundreds of miles beyond the ordinary range of radio communications [2]-[4].

Several factors that can affect radio signal propagation are terrain, building, vegetation, carbon dioxide (CO_2) concentration and weather. Weather parameters such as rain, wind, temperature and humidity have been studied by many authors [2]-[8]. A group of researchers from Singapore decided to concentrate on the analysis of the combined effect of wind and rain, which is often encountered in a tropical forest [5]. They found that the distribution of temporal fading components resembles a Rician distribution function. Its Rician K factor gradually decreases as the strength of either wind or rain increases due to the movement of the forest components. However, in the preliminary study of radio astronomical lines effect of rain below 2.9 GHz stated that the raindrop size does not give significant effect on the signal attenuation for frequency below 2.9 GHz [6]. An experimental study has investigated the performance of a passive UHF Radio Frequency Identification (RFID) based system under changing environmental conditions to facilitate increased technology exploitation which addressed the impact of temperature and humidity variations on the system response. It was concluded that there was a linear relationship between passive UHF RFID tags' resonant frequency and temperature at relative humidity (RH) of 50% and 80% [7].

It was also reported that as the ground surface temperature increases, the loss (path loss) in the VHF radio signal reduces with a gradient coefficient of 21.8dB/$^{\circ}$C [2]. Another finding is that as the air temperature increases, the loss of the VHF radio signal reduces, however with very smaller gradient coefficient of 7.5dB/$^{\circ}$C than the ground surface temperature. The observation of path loss against an increase in temperature is based on the weather condition when relative humidity (RH) is low. However, when the RH is high and the temperature is also high, the observation is relatively different. This is evident from another result which shown that as the RH increases, there was little increase in loss of the VHF radio signal with a gradient coefficient of about 2.32dB/$^{\circ}$C. Another research has investigated the influence of air temperature, relative humidity and atmospheric moisture on UHF radio propagation in South Western Nigeria using experimental, theoretical and statistical approaches. The results showed that there were significant influences of the three atmospheric parameters on UHF networks links within the region. Further evaluations reveal that relations between variations in air temperature (control factor) and the received signal strength (RSS) can be technically and instrumentally utilized for efficient link control in the region [8].

The weather of Malaysia has a nearly uniform temperature, high humidity and abundant rainfall and the wind is weak due to its location which is closed to the equatorial line. The annual temperature variation is less than 2°C, except for the east coast of Peninsular Malaysia as well as the north and northeast Sabah which are often affected by winter surges originating from Siberia during the northeast monsoon prevailing in the Northern Hemisphere winter. However, the annual variation is less than 3°C. Kuala Terengganu has a tropical wet climate with no dry or cold season as it is constantly moist (year-round rainfall). The annual average temperature is 26.7 ^{o}C (80^{o}F) [9], [10]. In this study, the effect of temperature on radio signal at KUSZA Observatory, East Coast Environmental Research Institute (ESERI), UniSZA, Merang, Terengganu is discussed. The main goals of the paper are to analyse the relationship between Radio Frequency Interference (RFI) and the temperature using statistical analysis currently the study on the correlation between radio signals and temperatures in Malaysia is still absent. The findings of this study will benefit radio wave propagation research field which includes radio astronomy observations, space science, wireless communication, satellite, antenna and mobile communication and also electromagnetic radiation (EMR) research for health.

II. METHODOLOGY

The methodology is as outlined in Fig. 1. Firstly, all equipment was prepared to conduct an observation. According to [11], site selection is very important for decision makers to propose where to determine the observation site. It was decided to perform the data collection at KUSZA Observatory, East Coast Environmental Research Institute (ESERI), UniSZA which is situated in Merang, Terengganu. KUSZA Observatory is located near the beach at 5° 32' 10" N and 102° 56' 55" E on top of the hill with low population density and tropical wet climate. Both RFI pattern and temperature were observed on 26th of August 2015. Statistical analysis was performed from 3600 data to determine the correlation between temperature change and the radio signal pattern.

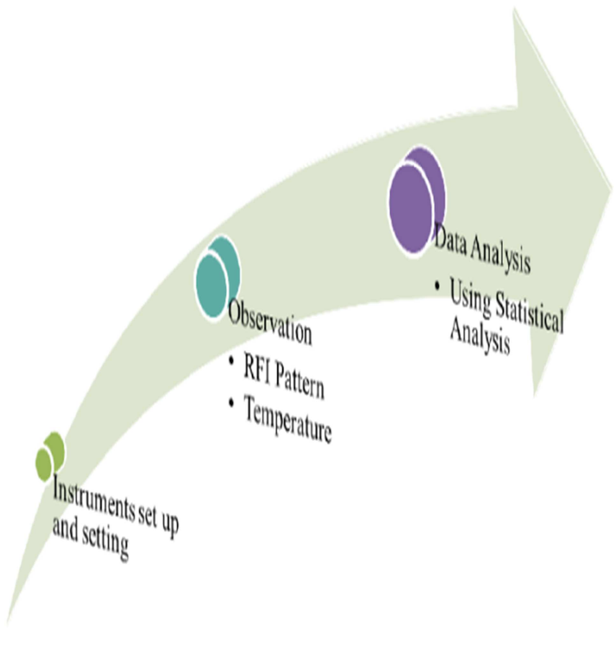

Fig. 1 The flowchart of the process followed in methodology

Fig. 2 shows the instruments setup for observation work. The instruments setup was adapted from [12] in their study which was investigated the effect of ambient CO_2 concentration on radio signal. Two sets of equipment were used in this observation. They were spectrum analyser (KEYSIGHT N9915A 9GHz, USA) which covers frequency up to 9 GHz with a resolution bandwidth 180kHz and weather station (Vantage Pro 2, USA). Spectrum analyser is used to detect the radio signal and weather station for temperature effect. Continuous-wave (CW) envelope fading waveforms were recorded over a period of the one-hour using patch antenna. The features of materials that are used for the microstrip patch antennas are presented in Table I.

TABLE I
CHARACTERISTIC OF MATERIALS

Characteristic	Radiator and Ground Planes	Dielectric Substrate
	Copper Foil Tape	**FR4 Board**
Thickness (mm)	0.04	1.6
Conductivity (S/m)	5.8×10^7	-
Dielectric constant	-	4.7

In this work, FR4 board was used as the dielectric substrate while adhesive copper foil tape was used as the radiator and ground plane. Patch antenna was connected to Low Noise Amplifier (LNA). The graph of radio signal attenuation for all frequencies below 9GHz was plotted to determine the frequency detected on site. The weather parameter (temperature) against time were plotted to see the pattern of temperature variation. The frequencies up to 9000MHz cover, at least, five radio astronomical sources including Hydrogen Line (HI) at 1420MHz, Deuterium (DI) at 327.384MHz, Methyladyne (CH) at 3263.794MHz and many more [12].

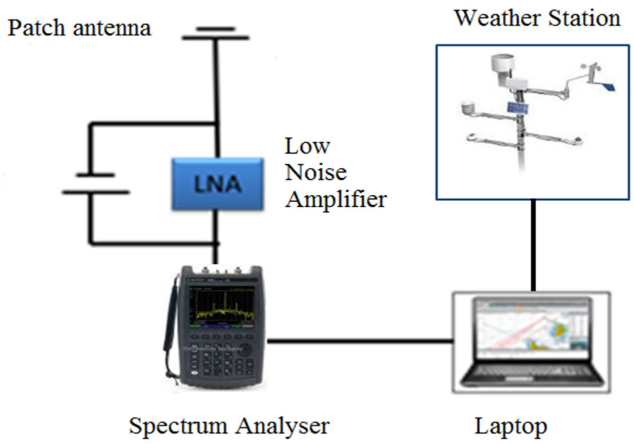

Fig. 2 The instruments setup for observation work [12]

From the data obtained, the correlation between the temperature variation and radio signal attenuation was determined to identify the relationship between them.

III. RESULTS AND DISCUSSION

From the tabulated data of power level versus frequency on a graph, it was found that there were four peaks of RFI at 383MHz, 945MHz, 1800MHz and 2160MHz (Fig. 3). Also, the frequencies of them are below 3000MHz and mostly come from digital trunked radio by Malaysia Communication Multimedia Commission (MCMC), FM Radio, Izzinet Sdn Bhd (Broadband Wireless Access (BWA) and DiGi (International Mobile Telecommunications-2000 (IMT2000) respectively [13].

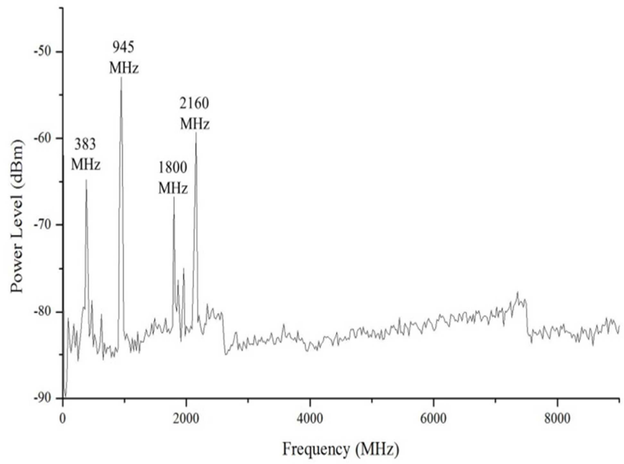

Fig. 3 The average of RFI/power level (dBm) vs frequency at KUSZA Observatory on 26th of August 2015

Apart from power level and frequency, temperature readings were also recorded simultaneously. The graphs of power level, changes in temperature (ΔT) versus Time are shown in Fig. 4-Fig. 7. Temperature reading increases slowly ranges from (0-0.2)$^{\circ}$C with the power level and time. Temperature changes were selected since the temperature reading fluctuates during the observation period. Therefore, for every frequency peaks the ΔT was plotted, power level against time. It can be concluded that almost all of the graph patterns showed similar trends.

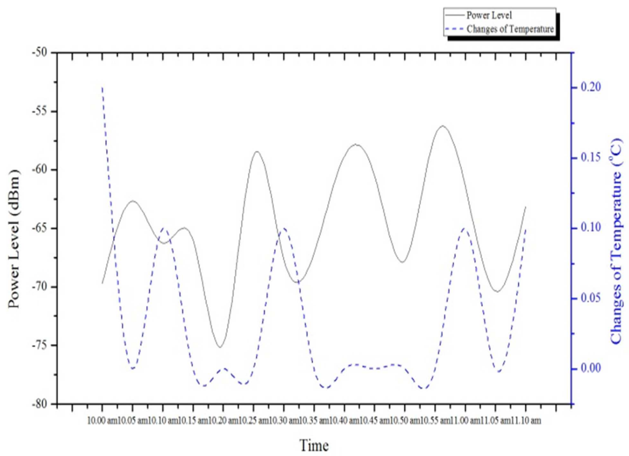

Fig. 4 Power level, changes of temperature versus time for 383MHz

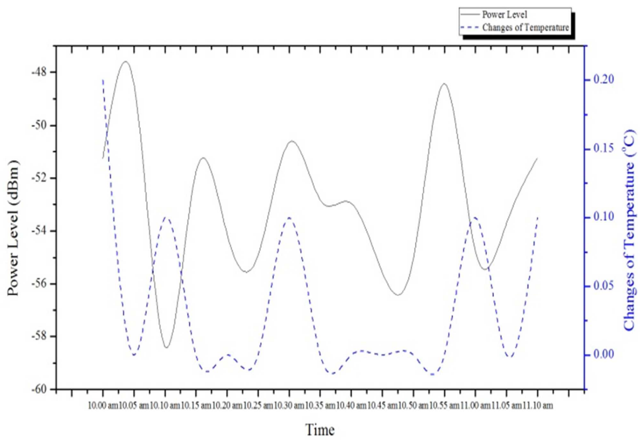

Fig. 5 Power level, changes of temperature versus time for 945MHz

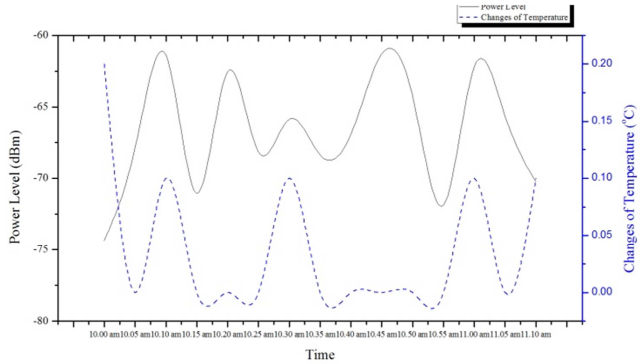

Fig. 6 Power level, changes of temperature versus time for 1800 MHz

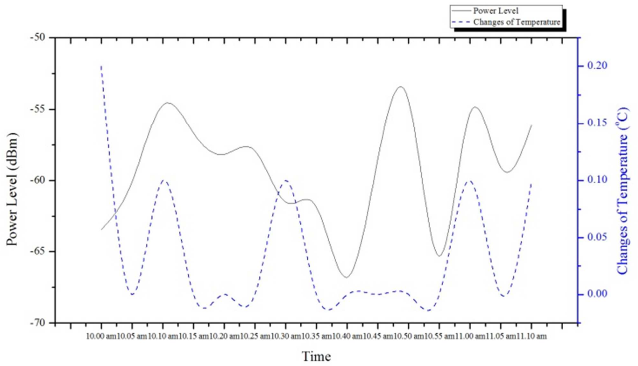

Fig. 7 Power level, changes of temperature versus time for 2160 MHz

The statistical analysis demonstrated that coefficient of correlations (r) for all four peaks ranges from (-0.085 to 0.268) and $p > 0.05$ (Table II). Table III shows the interpretations of the coefficient of correlations by Cohen in 1988 that we applied in this analysis [14].

TABLE II
COEFFICIENT OF CORRELATIONS (R) FOR THE RFI FREQUENCIES

RFI Frequency/MHz	Coefficient of Correlations, r	Determination of r
383	0.249	Small
945	-0.085	Small
1800	0.268	Small
2160	0.134	Small

TABLE III
THE INTERPRETATIONS OF THE COEFFICIENT OF CORRELATIONS BY COHEN 1988

Coefficient of Correlations, r	Determination of, r
0.10 to 0.29 or -0.10 to -0.29	Small
0.30 to 0.49 or -0.30 to -0.49	Medium
0.50 to 1.00 or -0.50 to -1.00	Large

From the output given above, the correlation between RFI frequencies and temperature give negative effect for frequency 945 MHz was r = -0.085, while for 383 MHz (r = 0.249), 1800 MHz (r = 0.268) and 2160 MHz (r = 0.134) was slightly higher. Thus, it proved that the relationship between the variables is weak and not statistically significant because of the $p > 0.05$. According to [14], it could be concluded that the temperature gives small significant effect on the radio signal with correlation coefficient nearly zero.

The findings indicate that there is a relationship between radio signals with the change of temperature. However, the correlation is weak where the coefficient of correlations, r is small which is below 0.3. This means that only 30% of temperature influence on the rest of the radio signal and may be further influenced by meteorological parameters. This finding is supported by [2]. Ground surface temperature and air (space) temperature have additional propagation loss effect on very high-frequency radio wave propagation. For thorough observation, the time duration for data collection should be conducted for 24 hours for more accurate results. In addition, the use various antenna, observation on several sites and the consideration of the temperature variation for the different season could be studied because there may be other parameters that can affect the weather such as the wind, rain, humidity and many more [15]-[20].

IV. Conclusions

Based on RFI pattern, four sources of the radio signal namely 383 MHz, 945 MHz, 1800 MHz and 2160 MHz could be detected at KUSZA Observatory. Based on the statistical analysis of the correlation between RFI and temperature, it could be concluded that the variation of weather factor (temperature) gave an effect on radio signals. Therefore, the temperature gives an effect to tropospheric radio signal strength for UHF band. These findings will benefit radio wave propagation research fields such as radio astronomy observations, space science, wireless communication, satellite, antenna and mobile.

Acknowledgment

This study was carried out by the grant RACE/F1/ST1/UNISZA/15(RR118), RACE-UM(CR008/ 2015), FRGS/1/2015/SG02/UNISZA/02/1, UMT-68006/ INSENTIF/60 and UniSZA/14/GU/023. The authors gratefully acknowledge Universiti Malaysia Terengganu, Universiti Sultan Zainal Abidin and Universiti Malaysia Perlis for the financial and experimental support of this work. Special thanks are also dedicated to other researchers Electromagnetic Research Group (EMRG) for their assistance in this work.

References

[1] J. Cohen, S. Titus, R. Ambrosini and W. V. Driel, CRAF Handbook for Radio Astronomy, 3rd ed., J. Cohen, T. Spoelstra, R. Ambrosini and W. van Driel, Eds., Strasbourg, France: European Science Foundation, 2005.

[2] M. O. Alade, "Investigation of the effect of ground and air temperature on very high frequency radio signals," Journal of Information Engineering and Applications, vol. 3, pp. 16-21, 2013.

[3] Cisco systems. (2013) [Online]. Available: http://www.cisco.com/c/en/us/support/docs/wireless/aironet-antennas-accessories/6609-intermittent-wireless-bridges.html.

[4] C. Boano, J. Brown, Z. He, U. Roedig and T. Voigt, Sensor Applications, Experimentation, and Logistics: Low-Power Radio Communication in Industrial Outdoor Deployments: The Impact of Weather Conditions and Atex-Compliance, ser. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. Berlin, Germany: Springer, 2010, vol. 29.

[5] Y. S. Meng, Y. H. Lee and B. C. Ng, "The effects of tropical weather on radio-wave propagation over foliage channel," IEEE Transactions on Vehicular Technology, vol. 58, pp. 4023-4030, Oct. 2009.

[6] R. Umar, N. H. Sabri, Z. Z. Abidin, Z. A. Ibrahim, A. Azid, H. Juahir, M. E. Toriman and M. K. A. Kamarudin, "Rain preliminary study of radio astronomical lines effect of rain below 2.9 GHz," Jurnal Teknologi, vol. 75, pp. 7-11, Jun. 2015.

[7] L. Zhenzhong, M. Nezih, X. George, O. Yuu, L. Guocheng and B. Dayan, “Effects of temperature and humidity on UHF RFID performance,” in Proc. CANSMART CINDE IZFP’11, 2011, p.1-10.

[8] A. A. Segun, A. M. Olusope and A. H. Kofoworola, “Influence of air temperature, relative humidity and atmospheric moisture on UHF radio propagation in South Western Nigeria,” International Journal of Science and Reserch, vol. 4, pp. 588-592, Aug. 2015.

[9] climatemps.com. (2015) Kuala Terengganu climate and temperature. [Online]. Available: http://www.terengganu.climatemps.com/.

[10] Climate of Malaysia. (2011) [Online]. Available: http://www.eoearth.org/view/article/151260.

[11] R. Umar, Z. Z. Abidin, Z. A. Rosli and N, Noorazlan, “Selection of radio astronomical observation sites and its dependence on human generated RFI,” Research in Astronomy and Astrophysics, vol. 14, pp. 241-248, Oct. 2013.

[12] N. H. Sabri, S. N. A. S. Zafar, R. Umar and W. Z. A. W. Mokhtar, “Radio frequency interference: The effect of ambient carbon dioxide (CO2), concentration on radio signal for radio astronomy purposes,” Malaysian Journal of Analytical Sciences, vol. 19, pp. 1065-1071, 2015.

[13] Malaysian Communications and Multimedia Commission. (2016) Spectrum management. [Online]. Available: http://www.mcmc.gov.my/ Spectrum/ Spectrum-Management.aspx.

[14] J. Cohen, Statistical Power Analysis for the Behavioral Sciences, 2nd ed., Oxford, UK: Routledge, 2013.

[15] J. Luomala and I. Hakala, “Effects of temperature and humidity on radio signal strength in outdoor wireless sensor networks,” in Proc. IEEE FedCSIS’15, 2015, p. 1247-1255.

[16] O. P. N. Calla and J. S. Purohit, “Study of effect of rain and dust on propagation of radio waves at millimeter wavelength,” in Proc. URSI’90, 1990, p. 151-155.

[17] R. Umar, S. S. Sulan, A. W. Azlan, Z. A. Ibrahim, W. Z. A. W. Mokhtar and N. H. Sabri, “Radio frequency interference: The study of rain effect on radio signal attenuation,” Malaysian Journal of Analytical Sciences, vol. 19, pp. 1093-1098, 2015.

[18] T. H. Chua, I. J. Wassell and T. A. Rahman, “Combined effects of wind speed and wind direction on received signal strength in foliated broadband fixed wireless links,” in Proc. EuCAP’10, 2010, p. 1-5.

[19] D. Bri, S. Sendra, H. Coll and J. Lloret, “How the atmospheric variables affect to the WLAN datalink layer parameters,” in Proc. AICT’10, 2010, p. 13-18.

[20] N. H. Sabri, A. W. Azlan, R. Umar, S. S. Sulan, Z. A. Ibrahim and W. Z. A. W. Mokhtar, “The effect of solar radiation on radio signal for radio astronomy purposes,” Malaysian Journal of Analytical Sciences, vol. 19, pp. 1374-1381, 2015.