iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** IV **Month of publication:** April 2019

DOI: https://doi.org/10.22214/ijraset.2019.4478

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

Effects of Building Material on Real Time Application in Radio Wave at Millimetre Wave Spectrum

Femi-Jemilohun Oladunni Juliet
Department of Electrical and Electronic Engineering, Ekiti State University, Ado Ekiti.

Abstract: ***The success of radio wave propagation in a building is affected by the topology, construction and materials of the building. UWB wireless communication is highly desirous and extensively engage by subscribers for real time applications due to its huge bandwidth potential with capability to deliver high data rate transmission. The impact of the properties of building materials on the way of Propagation at this frequencies calls for attention of the stakeholders, otherwise seamless transmission desired will be compromised and distorted. high frequencies are subject to rapid attenuation in presence of lossy materials like cement and glass which are the constituents of building where such transmission links will be deployed. This paper examines the effects of various building materials on wireless signals propagation at millimetre waves spectrum bands at 24GHz using Ubiquity airFibre 24GHz in indoor environment. A direct field strength measurement was used for this work, the results show that building materials have a significant effect on the wireless signal at this spectrum band.***

Keyword: lossy material, milimeter waves, Ubiquity air Fibre 24GHz, field strength, building.

I. INTRODUCTION

There is a strong demand for large transmission capacity as a result of unprecedented growth in data traffic, statistical reports show that mobile traffic is expected to grow 66 times more before the end of this decade [1], while the widespread use of micro cell wireless systems with corresponding limited frequency resources has led to inter cell interference [2]. Wireless communication are becoming routinely used by over 500 million consumers for a large variety of applications such as data transfer, internet access, audio and video streaming, and social networking. Considering the push by the insatiable demand for higher capacity bandwidth and the pull by a steady improvement of semiconductor technology, it is expected that the performance delivery of wireless standards is bound to increase seemingly without limitations [3].

Wireless propagation at high frequency has advantages of higher data rate transfer, which is crucial to support the large quantity of voice and live video streaming engage in by the huge number of subscribers of the services. However, high frequencies are subject to rapid attenuation in presence of lossy materials like cement and glass which are the constituents of building where such transmission links will be deployed. As radio waves impinge on different building materials through the various mechanism of propagation, the response of each material characterized by its electrical properties varies, building material property has a tangible effect on the transmission mechanism such as reflection and absorption of radio waves , this will lead to signal attenuation [4].

There is also high susceptibility of this frequency range to attenuation caused by weather such as rain, snow, and fog. Indoor and outdoor wireless signal leakages between propagation links are majorly caused by multipath interference due to reflection, diffraction and scattering. This can lead to the loss of the entire rf signal depending on the severity of such multipath impact.

This paper examines the effects of various building materials on wireless signals propagation at millimetre waves spectrum bands in indoor environment. A direct field strength measurement was used for this work, the results show that building materials have a significant effect on the wireless signal at this spectrum band.

The success of radio wave propagation in a building is affected by the topology, construction and materials of the building, a modern building with open plan design containing walls with large glass windows will give added pathloss of less than 5dB while a building made of thick stone walls with small windows and many internal solid walls will add an extra path loss of several tens of dB. Some of the physical effects of wireless indoor propagation are fast decay of signals, constrained coverage by walls, attenuation by walls [5]

A very important parameter for link planners is the building entry loss, this being on the increase but inadequately characterised partly as a result of variability of the building components, hence insufficient data and information availability about domestic buildings.

©IJRASET: All Rights are Reserved

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue IV, Apr 2019- Available at www.ijraset.com

One of the causes of the increase in BEL as stated by OFCOM in its report was the use of energy-efficient construction. While some metallic materials are of great importance for the improvement of the thermal performance of houses , these impact adversely on the transmission of wireless signals into and within houses. The knowledge of the construction industry about the impact of such practices on wireless radio coverage is still inadequate, therefore innovations to salvage the situation are not in view. There is a great need for awareness campaign in construction industry about the potential danger of such practices as the drive for Connected/ Smart Home drives progresses [4,6]

A. Conductivity and Signal Attenuation

The conductivities of metals engage in building construction are exceedingly high, therefore they are strong signal attenuators. In construction industry, the strong steel beams and radiators incorporated in building structures serve as good reflectors and signal attenuators especially at the frequency of interest. According to ITU, the conductivities of metals can be mathematically analysed from the first principle of Maxwell theory [7] as follows:

$$\nabla^2\vec{E} - \varepsilon\mu_o\frac{\partial^2\vec{E}}{\partial t^2} = \mu_o\frac{\partial\vec{J}f}{\partial t} \quad (1)$$

where:

$\vec{E}$: (vector) electric field intensity (V/m)

Jf : current density of free charges (A/m2)

ε : dielectric permittivity (F/m)

μ_o : permeability of free space.

$$\vec{J}f = \sigma\vec{E} \quad (2)$$

σ : conductivity (S/m).

$$\nabla^2\vec{E} - \varepsilon\mu_o\frac{\partial^2\vec{E}}{\partial t^2} = \mu_o\sigma\frac{\partial\vec{E}}{\partial t} \quad (3)$$

$$\vec{E} = \overrightarrow{E_o}e^{j(\omega t - \vec{k}.\vec{r})} \quad (4)$$

where:

$\overrightarrow{E_o}$: value of $\vec{E}$ for $t = \vec{r} = 0$ (V/m)

$\vec{k}$: (vector) wave number

ω: angular frequency

$\vec{r}$: (vector) spatial distance (m).

$$k^2 = \varepsilon\mu_o\omega^2 + j\omega\mu_o\sigma \quad (5)$$

where k is the magnitude of .

$$v = \frac{1}{\sqrt{\varepsilon\mu_o}} \quad (6)$$

$$\varepsilon = \eta\varepsilon_o \quad (7)$$

ε: relative dielectric permittivity of the medium concerned

ε_o: dielectric permittivity of free space (F/m).

$$v = \frac{c}{\sqrt{\eta}} \quad (8)$$

Where c is the velocity of light in free space

$$c^2 = \frac{1}{\mu_o\varepsilon_o} \quad (9)$$

$$\frac{c^2}{v^2} = \text{□} - j\frac{\sigma}{\varepsilon_o\omega} \quad (10)$$

$$\eta = \text{ή-}j\frac{\sigma}{\varepsilon_o\omega} \quad (11)$$

$$\eta = \text{ή} - \text{j}\text{ή} \quad (12)$$

where ή and ή are the real and imaginary parts

$$\text{ή} = \frac{\sigma}{\omega\varepsilon_o} \quad (13)$$

$$\sigma = 0.005563\,\text{ή}f_{GHz} \quad (14)$$

For the conductivity, there is usually statistically significant evidence for an increase with frequency. In this case the trend has been modelled using:

©IJRASET: All Rights are Reserved

$$A_{dielectric} = 1636\frac{\sigma}{\grave{\eta}} \quad (15)$$

$$A_{conductor}=545.8\sqrt{\sigma f_{GHz}} \quad (16)$$

$$\sigma = cf^{d}{}_{GHz} \quad (17)$$

where *c* and *d* are constants characterizing the material.

For the relative permittivity one can assume similar frequency dependency:

$$\grave{\eta} = af^{b}{}_{GHz} \quad (18)$$

where *a* and *b* are constants characterizing the material.

II. REVIEW OF RELATED WORKS

There is an increase demand for provision of seamless wireless coverage of all kind of wireless devices by the subscribers from their service providers for both indoor and outdoor propagation. The realization of this places a great task on the planner and designer of the infrastructure of the radio network. This may require the need for higher operating power, reuse of frequency for dense network or both. All of these will welcome the insurgence of interference within and between networks [4] Researches have shown that signal loss while penetrating building is directly proportional to operating frequency over a specific range while certain losses through building materials are inversely proportional with the frequency of operation. Nevertheless, the overall field strength of any transmission link is highly dependent on the structure of the indoor or outdoor arrangement of the scenario under study. Though the different ray paths mechanisms sometimes added up to improve the signal transmission from the direct path, the clustering layout within rooms of a building as well as transmission coefficients of buildings around can hamper this positive effect. The knowledge of the signal attenuation of various building material is highly imperative for the study, design and implementation of radio frequency propagation in the indoor and outdoor scenario especially at higher frequency of operation. It is no longer strange that some building material such as wood, glass, concrete ceiling and other metal surfaces obstructs and reduces the signal strength of electric field as it propagates through them. UWB wireless communication is highly desirous and extensively engage by subscribers for real time applications due to its huge bandwidth potential with capability to deliver high data rate transmission. The impact of the properties of building materials on the way of Propagation at this frequencies calls for attention of the stakeholders, otherwise seamless transmission desired will be compromised and distorted [9] Studies on relevant areas focused on frequency below 5GHz and 18GHz, this paper desires to complement research efforts by examining the impact of a cluster of building materials with the aim to acquire knowledge of the effect of smart building on the potential and performance of this future frequency bands in 24GHz with enormous bandwidth capable hundreds of Mbps. The FCC has provided flexibility in spectrum sharing by providing new opportunity for unlicensed spectrum usage with fewer restrictions on radio parameters, among the new radio system to exploit the novel [10] strategies for the increase of spectrum are Ultra Wide band (UWB), 60GHz millimetre wave band), and cognitive radios [11].The mm-wave bands at 24GHz, 28GHz, 38GHz and 60GHz have recently become major options for shorter-range, high-speed communication network systems: these bands can offer the Gb/s data rates required by multimedia consumer-oriented applications such as uncompressed video streaming and kiosk ash-downloading services [12][13]. It is well-known that the higher propagation losses encountered by millimetre waves can drastically reduce range (to that of a single room) unless high-gain antennas are used, however, this can be seen as an opportunity for frequency-reuse, thus increasing the aggregate network capacity in a dense office environment. Furthermore, an intrinsically limited range can mitigate interference between the various networks in the wireless system [12][14]. While an excellent and recent detailed study [15], investigated the 28 and 38 GHz bands with encouraging results, here, this work focused on the effect of building materials on the emerging 24.1-24.2 GHz unlicensed band using a 24GHz point-to-point link (Ubiquiti airFiber). Even with just 100MHz available bandwidth, this 24 GHz wireless link could support high bit-rate applications (up to 1.4 Gbit/s aggregate) due to reduced interference [16]. A typical application areas could be within public buildings, universities or hospitals with a range up to 150m. The mm-w spectrum band with licence free is replacing the 2.4 and 5GHz bands ptp links where interference is substantially reducing data throughput and sensitivity. 24GHz is in the millimetre wave band and has a very low noise floor because this band is not heavily laden with many devices. Though 24 GHz radio signals do not go as far as the 2.4 and 5 GHz bands because there is more atmospheric attenuation at this frequency and higher attenuation due to rain, however, radio waves are more directional as result of the narrower beam which concentrates the signal energy to the target. Radios at these frequencies have traditionally been very costly and bulky, few devices have been deployed on it, hence 24 GHz is an interference free frequency band at the moment and will not suffer the degradation and difficulties of the noisy situation peculiar to 2.4 and 5 GHz frequency bands. One of the best advantages of the 24 GHz band is its inherent security, the narrow beam makes it difficult to intercept the signal, and virtually all 24 GHz operation uses either horn or parabolic dish antenna [17].

©IJRASET: All Rights are Reserved

III. EXPERIMENTAL PROCEDURE

Here, we took advantage of a commercially-available 24GHz point-to-point wireless system (Ubiquiti airFiber), this wireless system uses either horn or parabolic dish antennas [11,13, 18]. This system featured both multiple-input/multiple-output (MIMO) technologies, dynamically variable signal constellations together with adaptive time/frequency multiplexing,
while both frequency and time division multiplexing are used in hybrid form: HDD; the combination of the best features of both TDD and FDD (e.g.interference-reduction and flexible band-planning) [19,20] enhances the realization of the specified 1.4Gbps delivery as established by the results of 128 the real-time application measurements conducted. Typically, <5dB mm wave excess path loss might be expected in an open-plan design modern building with large glass windows, in contrast, thick stone walls, small windows and many internal solid walls might add approximate 10s of dB excess loss [15], also, attenuation by walls, doors, furniture, and scattering are all to be expected in the chosen propagation environment. It is well-known that mm-wave links have intrinsically smaller Fresnel zones, as a guide, 60% othis zone should be unobstructed [21], otherwise it is deemed as NLOS as in the indoor environment. 24GHz point-to-point link used in these experiments had a narrow beam width of 3.5 degrees hence an obstruction smaller than the wavelength of the transmitted signal would cause scattering while a rough surface would diffuse the radio signal in all directions [22].



Fig 1:Experimental set up

During the measurement, the alignment of the TX and RX was maintained in height and Azimuth to ensure that the boresight of both antennas are on a straight line. The material under test was positioned perpendicularly such that the an orthogonal signal incidence of the wireless signal on the material is sustained. The report of measurement-based analysis of wireless signal attenuation of some building material in the indoor scenario is presented in this paper.
The experimental set up shown in Fig 1 consists of the 24GHz point-to-point link with maximum output of 20dBm. It has delivery capacity of 1.4Gbps using the HDD in bidirectional mode at 6X64 QAM modulation scheme (highest) and is backward compatible to lower modulation scheme of QPSK through the automatic rate adaptation to accommodate low signal
transmission. The feature enables a link pair to sustain up to 142.5 dB path loss when switched to basic QPSK modulation mode. Full duplex transmission is used with slight different carrier frequency of 24.1 and 24.2GHz and bandwidth of 100MHz. The transmitting and the receiving terminals have an antenna gain of 33dBi each. For the experimental measurement, both antennas were mounted on tripods 1.7m above the oor level, and connected to PC for signal transmission monitoring. This experiment was conducted in a laboratory where there were lusters of other devices hence the possibility of signal reflection and multipath propagation. The links were set at 3m apart and several measurements of the received signal strength of the link were recorded and the average was found to be -45dBm at this point. A board with cardboard and brown paper was positioned to obstruct transmission between the link at a distance of 1m away from the receiver and 2m away from the transmitter. An attenuation of 2dB was observed. This was done about 10 times with the same result, then, the board was made the reference point to deduce the attenuation of other office construction materials when hung on it and the recorded attenuations of various other building materials are shown in table 3, which are believed to the best of knowledge to be the first available at 24 GHz.

©IJRASET: All Rights are Reserved

IV. RESULT AND DISCUSSION

The interaction of wireless radio waves with building materials obstructing its line of sight propagation will result in signal attenuation that is highly dependent on the electrical properties of such materials and its structure. The electrical properties of some building material as presented by [4] is given in table 1.

Table 1: Material properties

Material class	Real part of relative permittivity		Conductivity S/m		Frequency range
	a	*b*	*c*	*d*	GHz
Concrete	5.31	0	0.0326	0.8095	1-100
Brick	3.75	0	0.038	0	1-10
Plasterboard	2.94	0	0.0116	0.7076	1-100
Wood	1.99	0	0.0047	1.0718	0.001-100
Glass	6.27	0	0.0043	1.1925	0.1-100
Ceiling board	1.50	0	0.0005	1.1634	1-100
Chipboard	2.58	0	0.0217	0.7800	1-100
Floorboard	3.66	0	0.0044	1.3515	50-100
Metal	1	0	107	0	1-100

In comparison to the existed work, table 2 and Fig 2 were extract of findings of [4]. The author measured the signal attenuation of some building materials at the microwave bands. While table 3 are the results of the attenuation of wireless signal by building materials at UWB by the author of this work.

Table 2: Signal attenuation for various building construction materials Microwave bands [4].

Material	Attenuation(dB)
Plasterboard	3-5
Glass with metal frame	6
Cinderblock wall	4-6
Window	3
Metal Door	6-10
Structure concrete wall	6-15

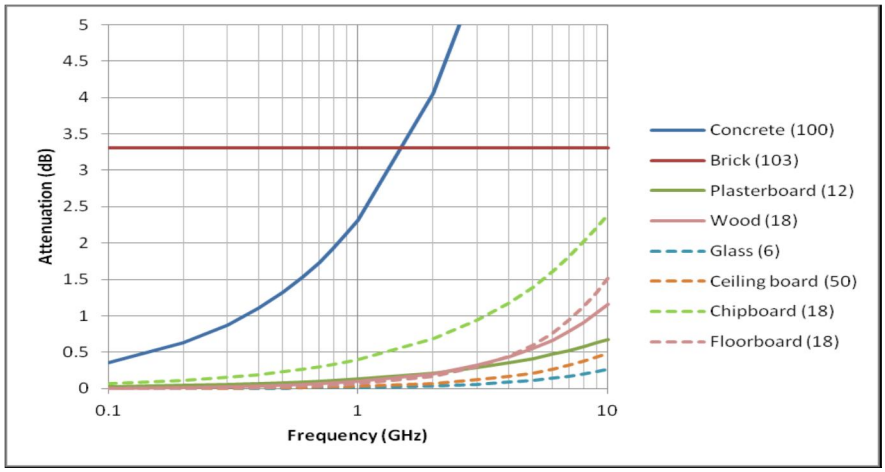


Fig 2:Attenuation of building material MMW (thickness in mm shown in legend) [7]

©IJRASET: All Rights are Reserved

Table 3: Signal Attenuation of various building material at MMW of 24GHz bands.

Material	Thickness (mm)	Attenuation (dB)
Plexiglas	5	3
Perpex	8	3
Black Plywood	11	4
Delrin	13	2
Plastic sheet	1.5	2
Hard board	3	3
Tufnell	6.3	2
Plexiglas Tinted	3.3	1

V. CONCLUSION

The regulatory agencies are intensifying efforts on how to maximise the scarce spectrum utilization, this is as a result of high demand for wireless communication connectivity by the consumers, which has resulted in the overcrowding of the available unlicensed spectra. Though the spectrum efficiency of some radio systems is encouraging, the challenge of increased interference at the same time has limited the network capacity and scalability, while some bands are poorly utilized. The presence of opaque or absorbing materials, corners of buildings, and window closed or opened in a building can impose enormous fluctuations in the wireless signal propagation at UHF bands thereby leading to high degradation of the transmission links. Spectrum at this band requires perfect line of sight transmission links, the signal strength level require to establish a link depends on the receiver sensitivity as well as interference and noise at the receiver. Therefore any trace of shadow regions formed as a result of obstruction to this, will disconnect the links from the wireless signal transmission. This can also lead to severe multipath causing a nearly complete loss of wireless signals as well as limit the coverage area and total loss of the intended information or data being transmitted. Though diffraction at edges and corners are sometimes advantageous, it causes illumination behind obstructions, and spreading through small apertures, thereby helps in extending propagation horizon.

Overall, though it has been demonstrated that gigabit throughput using the 24 GHz frequency band is an option for future 152 within-building wireless networks, a good attention is required both by researchers and construction industry to ensure adequate knowledge of the materials incorporated in the modern building so that the desire for seamless transmission of wireless signal will not be jeopardized.

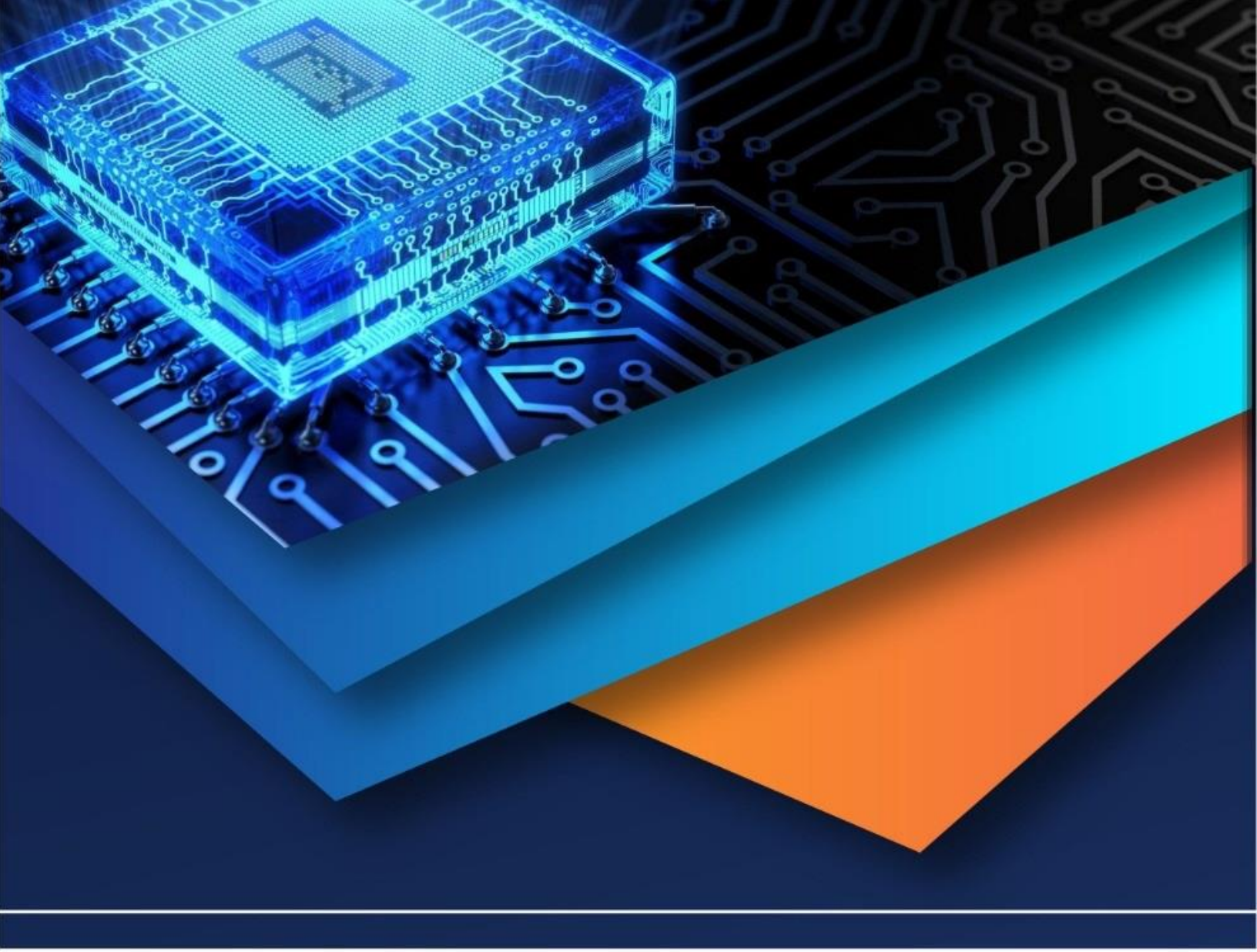
REFERENCES

[1] K. P. Makhecha and K. H. Wandra, “4g wireless networks: Opportunity and challenges," in India Conference (INDICON), 2009 Annual IEEE, pp. 1{4, IEEE, 2009.
[2] R. Kudo, Y. Takatori, K. Nishimori, T. Ichikawa, T. Murakami, M. Mizoguchi, and M. Morikura, \Spatial domain resource sharing for overlapping cells in indoor environment," International Journal of Digital Multimedia Broadcasting, vol. 2010, 2010.
[3] S. Pollin, M. Timmers, and L. Van Der Perre, Software de_ned radios:from smart (er) to cognitive. Springer, 2011.
[4] Richard R, Ken C, Martin G, Richard H “ Building Materials and Propagation” Final Report Ofcom, 2014
[5] Ignacio R, Huan C. N, Niels T. K. J, Troels B. and Preben M, “Radio Propagation into Modern Buildings: Attenuation Measurements in the Range from 800 MHz to 18 GHz” IEEE
[6] J. Voigt, J. Hubner, E. Forster, and G. P. Fettweis, \Design pattern for a single frequency tdma-system in a typical o_ce environment at 60 ghz," in Vehicular Technology Conference, 1999 IEEE 49th, vol. 2, pp. 1570{1574, IEEE, 1999
[7] Recommendation ITU-R P.2040-1 “Effects of building materials and structures on radiowave propagation above about 100 MHz” 2015
[8] Andrew C. M. A, Michael J. N,Gerard B. R, and Ryan J. P “Modelling the Effects of Nearby Buildings on Inter-Floor Radio-Wave Propagation” Ieee Transactions On Antennas And Propagation, Vol. Xx, No. Xx, January 2009
[9] Adeniran, .A.O. ,Ajao, S.O. and Obot, S.E. “Experimental Determination of Wireless Attenuation Loss of Some Nigerian Roofing and Ceiling Materials” International Journal of Applied Research Volume-4, Issue-1,201
[10] D. Cabric, M. S. Chen, D. A. Sobel, S. Wang, J. Yang, and R. W. Brodersen, \Novel radio architectures for uwb, 60 ghz, and cognitive and Networking, vol. 2006, no. 2, pp. 22{22, 2006.
[11] P. Smulders et al., \60 ghz radio: prospects and future directions,"in Proceedings Symposium IEEE Benelux Chapter on Communications and Vehicular Technology, vol. 8, 2003.
[12] A. M. Hammoudeh, M. G. Sanchez, and E. Grindrod, \Experimental analysis of propagation at 62 ghz in suburban mobile radio microcells," Vehicular Technology, IEEE Transactions on, vol. 48, no. 2, pp. 576{ 588, 1999.
[13] H. K. Pan, \Dual-polarized mm-wave phased array antenna for multigb/s 60ghz communication," in Antennas and Propagation (APSURSI), 2011 IEEE International Symposium on, pp. 3279{3282, IEEE, 2011.
[14] M. Fiacco, M. Parks, H. Radi, and S. Saunders, \Indoor propagation factors at 17 and 60 ghz," Radiocommunications Agency Report, 1998.

©IJRASET: All Rights are Reserved

[15] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K.Wang, G. N.Wong, J. K. Schulz, M. Samimi, and F. Gutierrez, \Millimeter wave mobile communications for 5g cellular: It will work!," Access, IEEE, vol. 1, pp. 335{349, 2013.
[16] G. Solution, \Ubiquity air_ber 24ghz point-to-point radio," Ubiquiti Networks, p. 10, 2012.
[17] S. Kavanagh, \An introduction to 24ghz," Kitohener Waterloo Amateur Radio Club, 2001.
[18] A. C. T. Workings, \Hardware and solution for the broadband wireless industry," Altius Communication Technology Workings Electronic Article, 2013.
[19] J. Laskar, S. Pinel, D. Dawn, S. Sarkar, B. Perumana, and P. Sen, \The next wireless wave is a millimeter wave," Microwave Journal, vol. 50, no. 8, p. 22, 2007.
[20] S. Yun, S. Park, Y. Lee, D. Park, Y. Kim, K. Kim, and C. G. Kang,\Hybrid division duplex system for next-generation cellular services,"Vehicular Technology, IEEE Transactions on, vol. 56, no. 5, pp. 3040{3059, 2007.
[21] Y. J. Sang, J. M. Park, S.-L. Kim, and K. S. Kim, \An overlaid hybrid division duplex ofdma system with multihop transmission.," ETRI Journal, vol. 33, no. 4, 2011.[15] S. M. Cherry, \Wimax and wi-_: separate and unequal," Spectrum, IEEE, vol. 41, no. 3, pp. 16{16, 2004.
[22] Digi, \Application note xst-an010a," Digi, p. 6, 2012.
[23] J. Zyren and A. Petrick, \Tutorial on basic link budget analysis," Application Note AN9804, Harris Semiconductor, 1998.
[24] Zhang Y.P “Novel model for propagation loss prediction in tunnels, "Vehicular Technology, IEEE Transactions on, vol. 52, no. 5, pp. 1308{1314, 2003.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)