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Investigation of Electromagnetic Radiations by GSM Base Stations in Nigeria for Compliance Testing

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Abstract
Thousands of base station antennas (BSA) have been installed in Nigeria to support the development of mobile telephony. At the same time there is a public concern about the electromagnetic fields induced by these antennas, particularly there is a great fear by those living in the vicinity of these antennas, of being exposed to the harmful effects of this radiation. This fear has created the need to investigate and establish the level and also to determine whether this level is harmful or not based on the International Committee for Non-Ionization Radio Protection (ICNIRP) Standards. In this study, field measurement approach was used to investigate the impact and compare the result with the safety standard as given by ICNIRP. The analysis of the result provided information on the radiation level in the university of Nigeria environment. The results showed that Odim location recorded the maximum power density of 0.1879 mW/m2, while PG recorded the minimum power density of 0.0158 mW/m2. The maximum power density value obtained occurred at 200m away from the foot of base station antenna. When this power density level was compared with the international safety level standard of about 4.5W/m^2, the result showed low radiation, 0.004 percent of the safety level.
Keywords: EMR, Base Station, Radiation, Measurement, Environment, Power Density

1.0 Introduction

Electromagnetic Radiation (EMR) has been identified to have adverse effect on biological/living organisms including man [1],[2],[3]. GSM base stations radiate these waves on their surrounding environment. Of greater concern are the advent of GSM Technology and the proliferation of communication masts both in rural areas and urban cities. The generality of the populace are becoming so uncomfortable and are daily expressing their fears on the possible ugly consequences of the emissions (radiations) from these masts. This study provides an investigative approach to EMR by GSM base stations for different locations and frequencies. It also offers a perspective on the potential implications for human health exposure to the pulsed microwave frequency currently used in GSM (Global System for Mobile Communications). This communications outfit differs from that currently espoused by mainstream science. It is a common knowledge that radio, television, and radar systems transmit radio waves in their environment but the frequency by which they operate differs from that of GSM wireless technology. The GSM wireless technology transmits continuous pulsed signal in its environment.

2.0 Related Work

Dina, Simunic in the paper [4], showed result of measurements taken around GSM base stations. In the work, measurements were taken at three different positions for three polarizations in the whole GSM downlink band. The measurement set-up consists of spectrum analyzer and a dipole antenna. The most significant values (''worst case'') were recorded and later converted to peak power density. Results were later compared with the reference level (ICNIRP), and found to be 100,000 times smaller than the reference level. Maximum value was about 0.029mW/m^2 and minimum value stood at 0.003mW/m^2. The case of cable losses was considered. However, he noted that errors are likely to occur in real urban electromagnetic environment with multiples sources as a result of close range of some base stations.

In a case study carried out in Romania [5], where measurements were based on compliance testing; a portable measurement system TS-EMF, spectrum analyzer was used for the measurements. The system was computer driven, while the R&S (Rohde & Schwarz) REFX software enables data acquisition and settings management. The power density level recorded from GSM 900 BSA (Base Station Antenna) in the far field was 0.75mW/m^2, which did not exceed the reference level when compared with ICNIRP standard level. A similar work was also carried out in Malaysia in a university environment [6]. They used the same set of equipment, TS-EMF spectrum analyzer. Electric field intensities and power densities were measured for all existing signal ranging from 80 MHz to 2.5 GHz. In this case, when the result of their findings was also compared with ICNIRP standard, the result showed about 34% lower than the reference level. The study intends to compare results with ICNIRP standard level as others did above.

3.0 Materials and Methods

In this study, the portable EMF measurement system, Spectran HF 6080 model, was used to measure the peak power from the mobile base stations. It is a professional piece of equipment which allows measurement of high frequency fields. It is also a frequency selective equipment which is calibrated between 0 to 1GHz (for GSM

900) and between 1 to 2 GHz (for GSM 1800). The measurement error expectancy is about ±3dBm, and this is referred to as the measurement uncertainty. This means that after measurements, the value 3dBm is to be added to compensate for the measurement inaccuracy. Example, if -45dBm is measured, adding 3dBm to it gives -42dBm.

Figure 1 shows Research Team setting up the Equipment.

Figure 2 shows Equipment position during measurement

3.4.1 Measurement of Power Density

To measure the power density from a mobile base station, the equipment was set-up in the vicinity of the base station. The equipment consists of three main components, which are these: Hyper Log 7025 Measurement Antenna, Spectran-HF 6080 and communication software installed in a laptop (Aaronia AG Software), as shown in figures 1 and 2. The Spectran-HF 6080 was connected to a Laptop for data logging. This is because the Spectran-HF 6080 has low memory capacity and therefore cannot accommodate large data.

The main concern here is to find the peak power density since the measured values are in peak power. To do this, equation (3.1) will be useful since the required parameters are known.

$$S_{peak} = (10^{(P-G)/10}/1000)*(4*\pi)/\lambda^2 \text{ [7]} \qquad (3.1)$$

where Speak represents the peak power density in (W/m^2), P is the measured peak power in (dBm), λ is the wavelengthh of the transmitter frequency (m), and G is the antenna gain (dBi) and the measurement uncertainty correction was assumed to be ±3dB.

4.0 Results and Discussion

This study sets out to determine the level of electromagnetic radiations by GSM Base Stations around their immediate environment, using the International Commission for Non-Ionization Radiation Protection (ICNIRP) recommendations as standard guidelines. These guidelines include high frequency radiation exposure measurements. Power density (S), measured in W/m^2, was used as a measure of the level of exposure to any electromagnetic radiation by the GSM stations. These measurements were conducted at the sites of a selected number of GSM Base Stations located at the Nsukka Campus of the University of Nigeria, as case study. Field measurements results were used in the study. This section presents the results of these measurements, and an analysis of the results revealed the following findings of the study: i) The power density (S) decreased as the distance from the foot of the antenna base stations increased and then decayed exponentially as the distance increased beyond 300m. ii) The power density also increased gradually from the foot of the antenna base stations due to the side lobes until it reached a maximum point where the main beam touched the ground, then it decayed exponentially with distance, becoming negligible beyond the distance of 300m. iii) The maximum power density values occurred at a distance between 200m and 300m away from the base stations. iV) Power densities varied from one base station to another, depending on a variety of prevailing factors at the base stations, as well as between GSM900 and GSM1800 as a result of frequency differences; and V) The maximum power density observed was within GSM 900 frequency and at a distance of about 200m away from the foot of any antenna base station.

4.1 Field Results

Tables 1 and 2, show measured data collected at four different locations for GSM 900, and GSM 1800, respectively. Tables 3 and 4, each represented the values calculated from tables 1 and 2, respectively. The measured data were recorded in peak power values with units in dBm, while the calculated values were converted to peak power densities and expressed in mW/m^2. This is because radiation levels are usually expressed in terms of power density levels with units in W/m^2. Both tables 3 and 4 are also shown graphically in figures 3 and 4, respectively. Table 5 gives the summary of the radiation levels observed in all the locations in terms of power densities.

Table 1: Measured Power of GSM 900 (dBm).

DISTANCE (m)	ARTS	ODIM	CLUB	PG
50	-51.03	-58.25	-44.29	-58.54
100	-48.05	-32.6	-35.3	-34.95
150	-48.7	-31.65	-52.22	-50.14
200	-46.02	-22.94	-31.63	-34.29
250	-46.68	-43.4	-54.96	-55.94
300	-57.6	-35.42	-33.45	-33.22

Table 1 above shows the measured data at peak power of GSM 900, expressed in dBm. This was later converted to Power Density, expressed in watts per metres squared (W/m^2), using equation (3.1), as given in section.

Table 2: Measured Power of GSM 1800 (dBm).

DISTANCE (m)	ARTS	ODIM	CLUB	PG
50	-47.03	-54.06	-53.29	-59.44
100	-44.69	-44.93	-45.64	-55.77
150	-43.42	-60.44	-48.53	-53.2
200	-33.87	-49.22	-37.72	-51.47
250	-48.09	-60.71	-57.77	-49.09
300	-47.03	-56.41	-47.55	-62.45

Table 2 shows the measured data at power of GSM 1800, expressed in dBm. This was also converted to Power Density expressed in watts per metres squared (W/m^2) using equation (3.1).

Conversion Formula: $S_{peak} = (10^{(P-G)/10}/1000)*(4*\pi)/\lambda^2$ [7]

Table 3: Calculated Power Density of GSM 900 (mW/m^2)

DISTANCE(m)	ARTS	ODIM	CLUB	PG
50	0.000320	0.000054	0.000116	0.000056
100	0.000554	0.020100	0.000219	0.000327
150	0.000637	0.025016	0.001362	0.000394
200	0.000873	0.185879	0.010795	0.013202
250	0.001010	0.001671	0.016528	0.015162
300	0.000070	0.001050	0.007325	0.005511

Table 3 shows the calculated power density from the measured data in peak power for GSM 900 at the four different locations expressed in mW/m^2.

Table 4: Calculated Power Density of GSM 1800 (mW/m^2)

DISTANCE (m)	ARTS	ODIM	CLUB	PG
50	0.001127	0.000223	0.000266	0.000064
100	0.002266	0.000916	0.000798	0.000150
150	0.001933	0.001292	0.001000	0.000272
200	0.023350	0.002154	0.001553	0.000405
250	0.000883	0.000048	0.009622	0.000701
300	0.001127	0.000130	0.000095	0.000032

Table 4 shows the calculated power density from the measured data of power of GSM 1800 at the four different locations expressed in mW/m^2.

Table 5: Summary of Power Density Levels (mW/m^2)

LOCATIONS	GSM900	GSM1800	TOTAL
ARTS	0.0010	0.0233	**0.0243**
ODIM	0.1858	0.0021	**0.1879**
CLUB	0.0165	0.0096	**0.0261**
PG	0.0151	0.0007	**0.0158**

4.2 Analysis of Results

This section presents an analysis of the above results according to the stated aims and objectives of this work. In this study, technical data on antenna parameters extracted from the literature was used for the simulations. Such parameters include: antenna gain, losses, etc. [8],[9],[10]. The ICNIRP recommends power density safety level of about 4.5W/m^2 for general public exposure [11],[12]. This covers the frequency range between (400 MHz to 2,000 MHz) in the far field. Far field here refers to distances greater than 10 metres away from the base station antenna [1],[13]. The implication is that, any radiation level (in terms of power density), found greater than the safety level standard (ICNIRP) may have serious health problems if it is in contact with humans. This is the reason(s) why Nigerian Communications Commission (NCC) forbids the erection of GSM Base Stations near residential areas as found in [14]. Two of the most important factors considered during measurements were distance and direct line of sight [15], for accurate result.

4.3 Comparisons of Locations for GSM900 and GSM1800.

Here, results from selected base stations were compared as shown in figures 3 and 4 below.

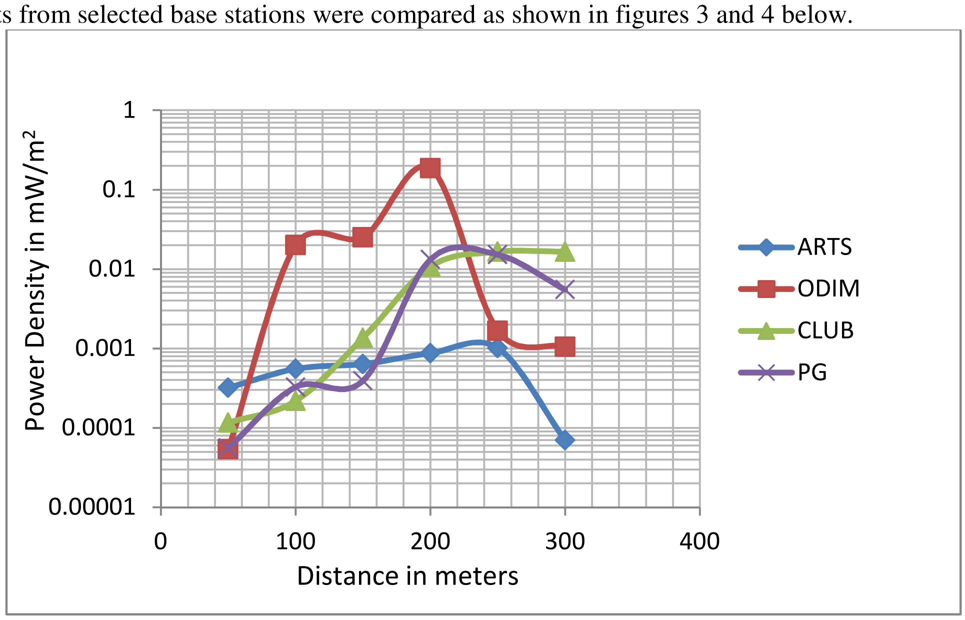

Figure 3 Graph Comparisons of Locations for GSM 900

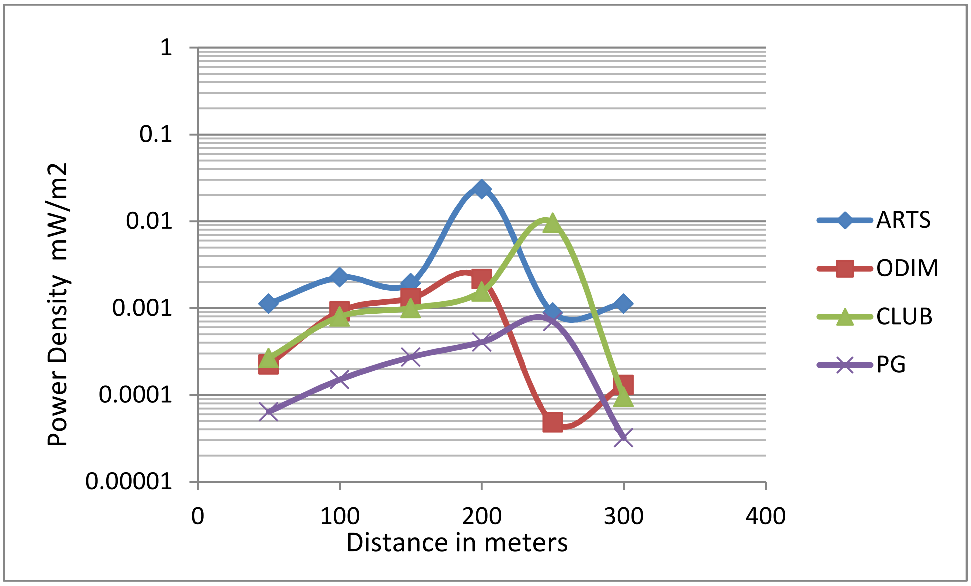

Figure 4 Graph Comparisons of Locations for GSM 1800

There was a noticeable gradual rise and fall of power densities before the maximum was reached as illustrated by graphs in figures 3, and 4, respectively. These graphs represented the comparisons between locations. The maximum power density values occurred at a distance between 200m and 300m away from the base stations. Power densities varied from one base station to another, depending on a variety of prevailing factors at the base stations, as well as between GSM900 and GSM1800 as a result of frequency differences. The maximum power density observed was within GSM 900 frequency and at a distance of about 200m away from the foot of any antenna base station. Again, it recorded low power densities at Odim and PG in GSM1800. This may be attributed to the rate at which the base stations were being accessed by the subscribers at the point of measurement, or, other factors such as attenuation, shadowing effects, [9],[10],[11],[7],[8]. The power density also might drops due to congestion or over loading. But the very low measured values may have been distorted by ambient noise [17]. More trees were noticed at PG, and Club, than in other locations. Also, the numbers of channels observed were six (6) in each case, except for Club, which has 3 channels. These also affected the readings. Table 5 gives the sum total of the power densities measured in each of the locations for both GSM900 and GSM1800, respectively. In all, the total power density level measured was more at Odim with a value of 0.1879 mW/ m^2, followed by the Club with a value of 0.0261 mW/ m^2. Others were the faculty of Arts, with a value of 0.0243 mW/ m^2, and the PG School, with a value of 0.0158 mW/ m^2. Hence, the total radiation level in the environment under discussion stood at 0.2541mW/m^2. The issue still remains that the farther away one is from the base station, the lesser the radiation encountered within his environment. Figures 5 and 6 present two of the selected base stations where measurements were carried out. Figure 5, shows base station location at the Faculty of Arts, while figure 6, is the base station location at Odim.

Figure 5 Base Station located at the faculty of Arts

Figure 6 Base Station located at Odim

4.4 Discussion

Measurements were conducted at different distances (multiples of 50m up to 300m), and locations, using frequency selective equipment (spectrum analyzer) to obtain peak power values. The peak power values were later converted to peak power density values using equation (3.1). The results showed that the radiation level was dominant at Odim when compared with other locations, as shown in figure 3. Power densities varied from one base station to another, depending on a variety of prevailing factors at the base stations, as well as between GSM900 and GSM1800 as a result of frequency differences. Amplitude fluctuations were also detected during measurements and this may be attributed to the rate at which the particular base station was being accessed by subscribers. This might cause the peak power either to increase or decrease, vice versa. The effects of phone traffic, and discontinuous transmission (which is inextricably linked to the number of channels) on the power radiated which are incorporated in the R. Cicchetti et al analytical model is used for assessing EM radiation in the vicinity of a base station antenna [10].

There are different Network Operators providing GSM services at the University of Nigeria, Nsukka campus. Measurements were made in the most sensitive areas around the campus, tracking the peak values over 6-minute intervals, which is an acceptable standard [18]. The results are as presented in tables 1, and 2, respectively. Readings were collected in the following locations: Faculty of Arts, represented by 'Arts', Odim-gate, represented by 'Odim', Staff Club, represented by 'Club', and Postgraduate School, represented by 'PG'. The sites were selected based on the anticipated number of traffic around them because of the high population density noticed around them. This was done irrespective of the Operator involved. Again, our target was to capture the influence of traffic channels around those areas. This is because the broadcast control channels (BCCH) transmit continuously even if no subscriber is accessing the base stations [20]. But in the other hand, the traffic channel (TCH) fluctuates whenever subscribers are accessing the base stations. The existence of a large number of scatterers and absorbing objects around the visited sites lead to highly non uniform field distribution in the environment of BSA. As a consequence, this brought about shadowing and fast fading effects. Houses, trees, cars, and other objects, seen around the sites can lead to signal variations that can only be determined by very large measurement campaigns. This is one of the limitations of the study. It was difficult to carry out large measurement campaigns due to the fact that the equipment was borrowed and must be returned within a given time frame. The buildings alone can cause a strong shadowing effect that makes the field distribution to be very heterogeneous [19],[20],[21],[22]. Again, it was found from literature that wet trees absorb signals more than dry trees [23],[24]. This is a factor that can cause signal variations within the environment.

However, the maximum power density measured was 0.1879mW/m^{2,} at Odim, a distance of about 200m. This confirmed that power density occurs between 200m to 300m after which it decreases exponentially with I/r^2 [10],[25]. When compared with the ICNIRP safety level standard of 4.5W/m^2, it was found to be 0.004 percent of the recommended safety level

5.0 Conclusion

The study has also provided concrete data in terms of quantitative measures on radiation levels generated by individual base stations at certain locations. These concrete data measured in all the four locations are as follows: Odim recorded 0.1879 mW/m^2; followed by Club with 0.0261mW/m^2, Arts with 0.0243mW/m^2, and PG with 0.0158 W/m^2. The analysis of the field results provided the threshold for possible health risk at given locations of certain base stations. The result of the investigations was compared with international safety level standard for public exposure as given by ICNIRP, and was found to be far below the recommended safety level standard for public exposure, 0.004 percent of the recommended level. Going by the low level of radiations obtained from the various locations cited in the study, it is a sure proof that the Operators complied with the international guidelines on public exposure as given by ICNIRP. Notwithstanding the low level of radiation obtained, it is still difficult to delineate a threshold below which no effect occurs, however, it has been suggested that power densities around 0.5mW/m^2 to 1mW/m^2 must be exceeded in order to observe an effect [26]. This is due to the fact that cause and effects are not immediate.

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References

[1] Pozar, D.M. Microwave Engineering, John Wiley and Sons, Inc .3rd Edition, 2005.
[2] Kraus, J.D and Fleisch, D.A: Electromagnetics with Applications, McGraw-Hill, 5th Edition, 1999.
[3] Hyland, G.J. The Physiological and Environmental effects of non-ionizing electromagnetic radiation. European Parliament, Bruxelles, March, 2001.
[4] Forigo, D., et al '' *Measurements and numerical evaluation of the electric field in the near-zone of radio base station antennas'',* Antennas and Propagation Society International Symposium, IEEE, Vol. 3, 338-341, 2001
[5] Getsov, P.,et al , ''*Methods for monitoring electromagnetic pollution in the Western Balkan environment'',* SENS 2007 Third Scientific Conference with International Participation Space, Ecology, Nanotechnology, Safety, Varna, Bulgaria, 2007.
[6] Hamid,R. ,etal, '' *Measurement of electromagnetic radiation from GSM base stations'',* IEEE International Symposium on EMC, TUBITAK-UME, 41470, Gebze, Turkey, 2003.
[7] Spectran 6080 Manual (2007): Hw Rev /Firmware V1.101 by Aaronia AG, Germany. www.aaronia.de
[8] S.M. Mann, T.G. Cooper, S.G. Allen, R.P. Blackwell, A.J. Lowe, Exposure to Radio Waves near Mobile Phone Base Stations, NRPB, June 2000.
[9] Wiart (2001).'Data on COST 244bis`Short term Mission on Base Station Exposure'.
[10] R. Cicchetti, A. Faraone; "Estimation of the Peak Power Density in the Vicinity of Cellular and Radio Base Station Antennas," *IEEE Trans. On Electromagnetic Compatibilit*y, vol. 46, no. 2, May 2004.
[11] ETSI (1996). `Radio Network Planning aspects'. ETR 364 (GSM 03.30 Version 5.0.0) European Technical Standards Institute. November, 1996.
[12] Md. Rafiqul Islam, et al ''Radiation Measurement from Mobile Base Station at a University Campus in Malaysia''American Journal of Applied Sciences 3(4): 1781-1784, 2006.
[13] Ahaneku, M.A; Nzeako, A.N (2012): 'GSM Base Station Radiation Level: A Case Study of University of Nigeria Environment'. Publication in International Journal of Scientific Technology and Research, vol.1, issue 8.pp. 102 – 107.
[14] www.gsma.com/publicpolicy/wp-content
[15] Sabah, Hawar Saeid; ''Proceedings of the Conference on Electronics and Communications Systems'', 2013.
[16] Dina, Simunic ''Measurement and Exposure Assessment for Standard Compliance'' Report of Bulgaria National Program Committee 2003. http//:www.who.int./entity/publications/reports/en/Bulgaria.
[17] GSM measurements with selective radiation meter SRM- 3000. www.narsda.s-t-scom/3000.
[18] Mustafa Ergin et al; ''Selective Radiation Measurement for safety Evaluation on Base Stations'' Gazi University Journal of Science, 26(1): 73 - 83 (2013).
[19] Miclausi, S. and P. Bechet, "Estimated and measured values of the radiofrequency radiation power density around cellular base stations," Romanian Journal Physics Vol. 52, Nos 3-4, Pp429-440. Bucharest, 2007
[20] Y. Hamnerius, T, Uddmar, "Microwave Exposure from Mobile Phones and Base Stations in Sweden", Internal Report, Department of Electromagnetics, Chalmers University of Technology, 2008, pp. 52-63.
[21] P. Stewart, "The Mobile Phone System and Health Effects", Australian Radiation Protection and Nuclear Safety Agency, 8 June 2000, pp. 323-331.
[22] S. Jochen, "Mobile Communications", 2nd Edition, Addison Wesley, 2003.
[23]] Igo, Lacan and Joe R. McBride, ''City trees and Municipal wifi Networks: Compability or Conflict?'' Scientific Journal of International Society of Arboriculture, and Urban Forestry 35(4): pp.203 – 210, 2009.
[24] Nwawelu, U.N et al; (2012):'The Limitations of campus wireless Networks: A case study of University of Nigeria, Nsukka (LIONET) publication in International Journal of Networks and Communications,' Vol.2,

No. 5. Pp.
[25] RE Okonigene; ''Siting of GSM Base Station Antenna and Its Health Consequences'' Information Technology: New Generations (ITNG), 2010 Seventh International Conference on ICT, IEEE Xplore 2010 conference publications.
[26] Kundi M, Hutter HP; '' Mobile Base Station – Effects on wellbeing and health''Institute of Environmental Health, Centre for Public Health, Medical University of Vienna, Kinderspitalgasse 15, A – 1095 Vienna, Austra. www.nccb.nim.nih.gov.2013

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