Analysis of Cell Tower Radiation, RF Safety and Practical Realization of Compliance Distance

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Abstract- The effect of electromagnetic radiation on human health is the subject of recent interest and study. ICNIRP (International Commission on Non-Ionizing Radiation Protection) study has concluded that the exposure levels due to cell phone base stations are generally around one-ten-thousandth of the guideline levels. Moreover, the WHO has classified mobile phone radiation on the IARC (International Agency for Research on Cancer) scale into Group 2B–possibly carcinogenic to humans. It means that there could be some risk. On the other hand, telecom service providers are worried about QoS (quality of service) of mobile services about implementation of stricter norms regarding cell tower radiations. Therefore an exercise was done to measure cell tower radiations at various places of dense urban regions, in the context of QoS measurement at these places. Exercise was also done to understand near field behavior of mobile towers and practically realization of compliance distance. This paper deals with practically observed radiation level (power density) and QoS benchmarks at various sample points along with practically realization of safer zone from cell tower radiation point for various sets of EIRP/ERP, antenna gains, frequency bands etc. Comparison among theoretical and practically observed values of signal strength/power density/EIRP was also done with MATLAB program**.**

Index Terms- Cell tower radiation, Compliance Distance, EIRP, ICNIRP, Power Density, and QoS.

I. INTRODUCTION

Cell phone technology has grown exponentially in the last decade. Large number of BTSs/towers is to be deployed to meet the communication demand. Presence of large number of cell phone towers in populated area starts the debate on biological impact of cell tower radiation. Most of the countries have adopted the radiation norms as suggested by the ICNIRP. As per the ICNIRP, the value of power density at general public exposure zone should be less then f/200 watt/m^2 for 400-2000 MHz band. Here f (in MHz) is the frequency used by the mobile operator. Still some researchers are demanding to strengthen the radiation norms i.e. recommended value of power density at safer distance (that is exposing to general public) should be as low as possible. At the same time telecom service providers are opposing such demands and arguing that reduction in transmitted power/EIRP (effective isotropic radiated power) for reducing the risk of radiation may hamper the QoS of mobile operation.

Some researches theoretically prove that presence of large number of antennas on single tower with multiple carriers. from each antenna may cause sifting of compliance zone very far away from the tower and general public exposure area comes in exceedance zone where power density is very much higher than the recommended value.

Hence a research was done to measure cumulative power density from cell towers at some selected dense populated urban areas and QoS parameters were also measured to analyze both power density (radiation level) and QoS in collective manner.

A research was also done to measure radiation level at various distances for various sets of BTS /mobile towers to understand near field behavior of mobile antennas and to find out the compliance distance and its dependency on various factors like antenna gain, transmitted power, bands etc. A software model was also designed with mathematical formula using ASP.NET, which gives the calculation of Compliance distance, QoS and EIRP/EIRPth.

(i) EMF EXPOSURE ZONE

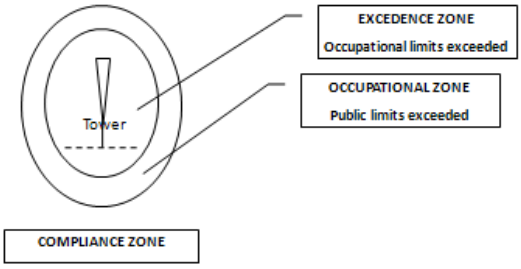

Figure 1- EMF exposure zone

A. Excedence zone – This zone has restricted access to workers and the general public.

B. Occupational zone- This zone is restricted access to general public. Physical barriers lock out procedures or adequate signs can accomplish the access restriction. Workers may be permitted to enter the occupational zone.

C. Compliance zone- This has EMF value below the applicable limits and it is treated as safer zone for general public.

(ii) Power Density and radiation level

The power density at any distance from an isotropic antenna is simply the transmitter power divided by the surface area of a sphere at that distance. The surface area of the sphere increases by the square of the radius, therefore the power density, PD, (watts/square meter) decreases by the square of the radius.

$$S = \frac{PG}{4\pi R^2}$$

Where, S = Power density (W/m^2),
P = Power input to the antenna (W)
G = Power gain of the antenna
R = Distance to the center of radiation of the antenna (m)

II. ANALYSIS OF CELL TOWER RADIATIONS

Cell tower radiation measurement methods can be classified in three categories:-

1. Calculation method
   a. Prediction of RF fields
   b. Calculation to determine $EIRP_{th}$
2. Software simulation
3. Field measurement

Field measurement approach was chosen to analyze cell tower radiations in various regions.

Measurement Approach:

Six sites were chosen for measurement. Following were considered in area selection

1. Area should be such that it should be covered by all major GSM operators radiating with GSM 900 & 1800 MHz CDMA 800 bands.
2. Large number of closely situated shared towers with many antennas should be present in that dense urban area.
3. Preferably it should be border area of two or more PLMNs, so that interference/ radiations from nearby PLMNs can also be taken in to account.
4. Site data & other technical data regarding that area should be available.

Ghaziabad was chosen as area of interest as it has highly populated dense urban area with a lot of mobile towers very near to residential complexes and it is on the border of UP and Delhi. This also facilitates for the study of interference from nearby mobile networks.

Data regarding service providers, ARFCN, antenna height, transmitting power, antenna gain, BTS configuration were collected & Power density/ electric field strength/ magnetic field strength was measured in that area at various distances. Total six sites were selected in Ghaziabad; details of these sites are given in Table.2.

Table1- Area chosen for measurement

Site selected	Longitude	Latitude
G-150, Patel Nagar (RTT)	28°60'14.5''N	77°33'26.4'' E
Meerut Road (RTT)	29°41'48.6''N	76°57'52.9'' E
D-24/2, New RLY Station	29°41'48.6''N	76°57'53.2'' E
Kavi Nagar (GBT)	29°41'37.3'' N	76°59'00.8'' E
Sec-10, Raj Nagar. (RTT)	29°41'48.7'' N	76°57'52.8'' E
Shastri Nagar (GBT)	29°23'43.1'' N	76°59'27.2'' E

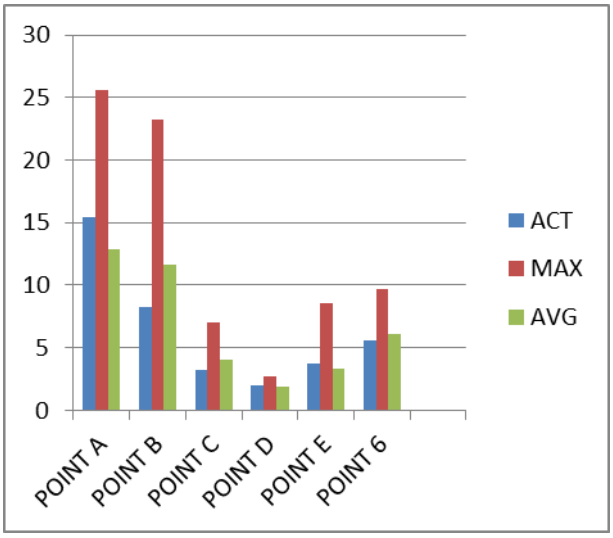

Figure 2- observed power density

Apart from that network quality reports related to that area were studied to see the QoS of mobile services. TEMS drive testing handset was also used to observe the network performance and personal interview was conducted to find out the QoS in term of customer satisfaction.

III. ESTIMATION OF QOS, COMPLIANCE DISTANCE, EIRP AND EIRPTH

For estimation of compliance distance, EIRP and EIRPth and quality of service of telecom operators, a model was prepared using ASP.NET.

A. QoS Calculation

To realize a QoS, a formula was formed. Particular Weightage was assigned to SDCCH drop, SDCCH block, TCH drop, TCH block, call setup success rate, RX power etc. given in Table 2.

Maximum value of QoS=1

Table 3-Weigtage assigned for QoS calculation

Sr.No.	Parameter	Weigtage assignment to Parameter as suggested by TRAI.
1	SDCCH BLOCK	1/20 if SDCCH block is < 1%, otherwise zero.
2	SDCCH DROP	1/10 if SDCCH drop is < 1%, otherwise zero.
3	TCH BLOCK	1/20 if TCH block is < 2%, otherwise zero.

4	TCH DROP	1/5 if TCH drop is < 2%, otherwise zero.
5	Call Completion success ratio	1/5 if CCSR > 95%, otherwise zero
6	Rx signal Strength	1/5 If Rx signal/l > -95 dBm, 1/10>-103dBm otherwise zero.
7	Rx quality.	1/5 for Rx Quality 0 to 3, 1/10 for Rx Quality 4 to 5, otherwise zero

Table4- Results Observed for QoS

Cell name	Site name	Operator name	QoS observed	
			Manual	Model
AKA001A	RAJ NAGAR	AIRTEL	0.8	0.8
AKA001B	SANJAY NAGAR	AIRTEL	1	1
ALR006A	MEERUT ROAD	AIRTEL	1	1
BBW001B	SHASTRI NAGAR	AIRTEL	0.6	0.6
KPN001C	KAVI NAGAR	AIRTEL	1	1

B. Compliance distance Calculation

Compliance distance can be calculated from the designed software model by putting the value of various parameters from site detail like Antenna gain, number of carrier/sec, Transmitted power, BCH frequency, feeder cable loss, combiner loss. Compliance distance calculation based on formula (for 400 to 2000 MHz).

Table5-Compliance distance recommended by ICNIRP (Based on ITU K.70 fact sheet formula)

Radio Frequency Range	General Public Exposure	General Public Exposure
1 to 10 MHz	$r = 0.10\sqrt{eirp \times f}$	r = 0.129√erp×f
10 to 400 MHz	$r = 0.319\sqrt{eirp}$	$r = 0.409\sqrt{erp}$
400 to 2000MHz	$\mathbf{r = 6.38\sqrt{eirp}/f}$	$\mathbf{r = 8.16\sqrt{erp}/f}$
2000 to 300000MHz	$r = 0.143\sqrt{eirp}/f$	$r = 0.184\sqrt{erp}$

Where r is compliance distance in meters, f is the frequency in MHz and EIRP is equivalent isotropically radiated power in the direction of maximum antenna gain in watt while ERP is effective radiated power in the direction of maximum antenna gain in watt.

Table6- Result Observed For Compliance distance

SITE ID	Compliance distances from Mathematical calculations	Compliance distances from Model
GZB_RJN	11.18m	11.19m
GZB_KN	17.36m	17.37m
GZB_mrt01	6.32m	6.31m
GZB_NRS	9.08m	9.08m
GZB_AK	10.58m	10.59m

C. EIRP and $EIRP_{th}$ model calculation

For estimation of EIRP and EIRPth Transmitting power, Antenna Gain, Combiner loss, BTS configuration, beam width (θ_{bw}), BCCH frequency, Antenna height, Antenna Tilt, R_x cable length, Side lobe attenuation and Cable unit loss (dB/100m) were taken as input for designing the software model. Following formulas were used for EIRP estimation.

(i) EIRP calculation

EIRP (BCCH) = P_t – Combiner Loss – (Cable Length × Unit Loss) + G_a (dBm)

EIRP [Total] = EIRP (BCCH) + EIRP (BCCH) ×0.9× 0.9 × (Carriers / Sector – 1)

(ii) EIRPth calculation

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$\frac{f\pi}{200A_{sl}}(h-2)^2$ $\frac{f\pi}{200}\left[\frac{h-2}{\sin(\pi+1.129\theta_{bw})}\right]^2$

Table7. Result obtain for EIRP and $EIRP_{th}$

SITE	EIRP (kW)	EIPRth (kW)
Meerut Road	0.25 KW	438.222 Kw
New RLY Stn.	0.502 kW	371.760 kW
Patel Nagar	0.755 kW	310.761 kW
Shastri Nagar	0.503 kW	330.487 kW

It can be realized that power density measured varies from 0.66 to 11.2mW/m^2 and the QoS is also between0.7 to 1. Ratio of practically observed and recommended power density varies from 0.028 to 0.0013 at compliance distances at these critical sites.

Hence it can be stated that telecom operators are radiating below the 1/100 to 1/1000 value of maximum allowable power density and even they were able to manage good QoS, so radiation norms can be further strengthen i.e. recommended power density at compliance distance may be f/2000 or less then it.

IV. Practical Realization of Compliance Distance

This exercise was done to realize compliance zone for a particular BTS/ antenna. Then various parameters like transmitted power, antenna gain, frequency, antenna height, tilt etc were vary to observe dependency of these factors on compliance distance.

Approach

A BTS site was chosen (test bed of GSM). It was not utilize by the general public so various parameters like frequency, transmitted power, hopping etc were changed & with the help of ANRITSU_MS2661A-11 spectrum analyzer and Narda SRM 3006 Frequency-selective meter power density/ electric field strength were measured at various points to find out the point where power density would be less then f/2000(W/m^2)& f/400(W/m^2) to find out compliance & occupational zone. Then graphs between observed power density/ electric field strength & distance was drawn for various sets of configuration (like transmitted power, antenna gain, antenna height, frequency etc) to observe the dependency of various factors on compliance distance.

Near field behavior was observed for the following specifications:-

Transmitting power- 43dBm, Antenna Gain= 17 dBi
beam width = 3 vertical θbw(deg)= 7.5
BCCH frequency= 949.2 MHz
Antenna height= 4m Antenna Tilt= 4 °
Rx cable length=32m, Side lobe attenuation=15 dB
Cable unit loss (dB/100m) = 3
Graph regarding observed power density at various places at compliance distance is shown below.

Observed Power Density ($Watt/m^2$)

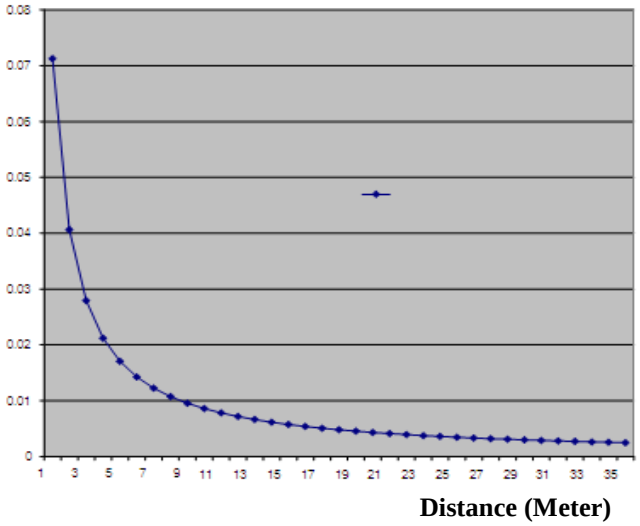

Figure 3 Observed Power Density

Graph shown above represent near field behavior of directional antenna. It is almost similar to exponential decay. Here if power density f/2000 considered for the compliance distance then it can be seen that observed compliance distance is between 3 to4 m for one carrier per sector.

Power Density ($Watt/m^2$)

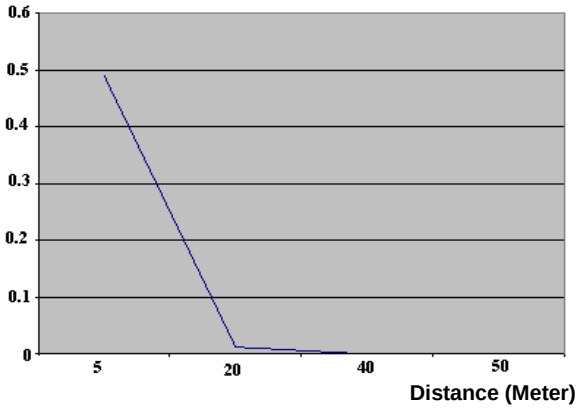

Figure4- Near field behavior of GSM antenna with 4 carriers in one sector

Graph shown above shows the near field behavior of GSM antenna with 4 carriers/sector. It can be observed that if power density f/2000 will be considered for the compliance distance then it can be seen that observed compliance distance is between 14 to 18 m. For 36 carriers the 57.5m was observed as compliance distance.Graph shown below represent electric field strength at various distances for various antenna gains. It can be observed that antenna with high gain offer higher value of power density/ electric field strength in near field region as compare to low gain antenna.

Electric field strength for various antenna gains Electric field Strength (V/m)

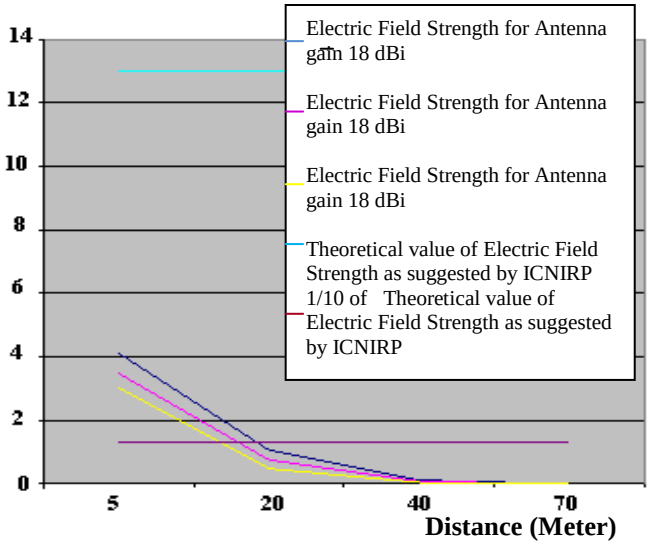

Figure 5- electric field strength at various distances for GSM 900 & 1800

Graph shown below represent electric field strength at various distance for GSM 900 & 1800 for the same transmitting power. It can be observed GSM 900 offers antenna with higher value of power density/ electric field strength in near field region as compare to GSM 1800.

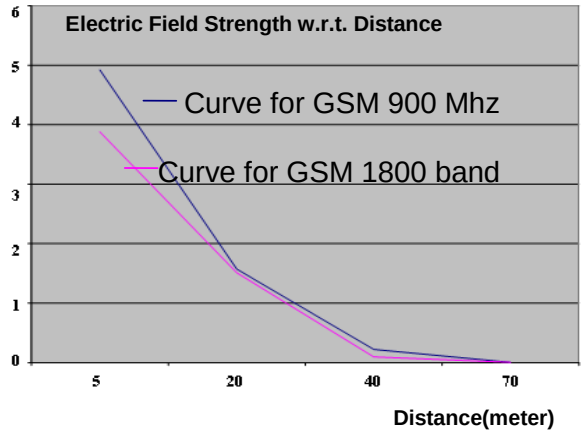

Figure 6- Electric Field Strength w.r.t. Distance

then observed compliance distance was between 2 to 3 m.(for maximum power transmitted i.e. 43 dBm & antenna gain 18 dBi) But this was the case of 1 carrier per sector. When 6 carriers were used per sector, then compliance distance increases by 4 times. for 36 carriers the observed compliance distance was 57.5m. As shown in graphs, compliance distance varies with antenna gain, transmitting power, frequency etc. It was also observed that frequency hopping did not put any influence on compliance distance.

V. Estimation of EIRP, Power Density and Path Loss using MATLAB.

MATLAB programmed designed for estimation of EIRP, Compliance distance and path loss with respect to various antenna gains, power and heights.

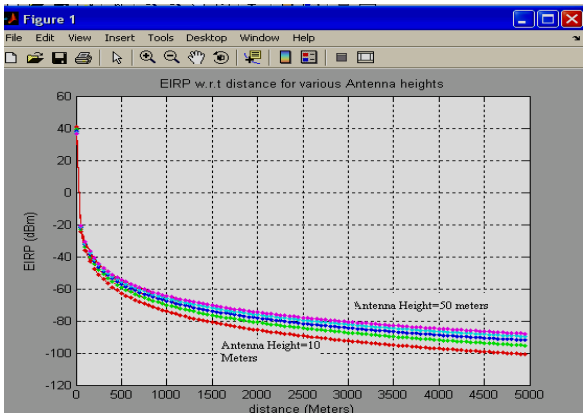

Figure7-EIRP w.r.t. distance for various antenna heights

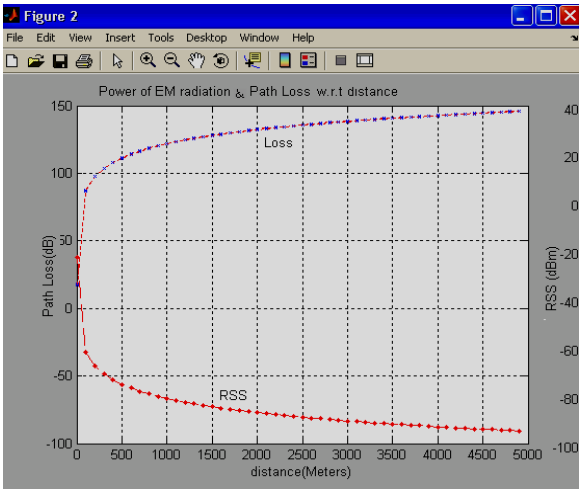

Figure8- Path Loss of EM Radiation and RSS w.r.t. different distances

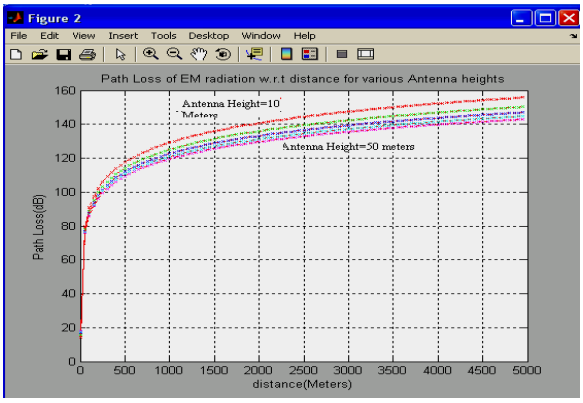

Figure 9- Path loss w.r.t. various antenna heights

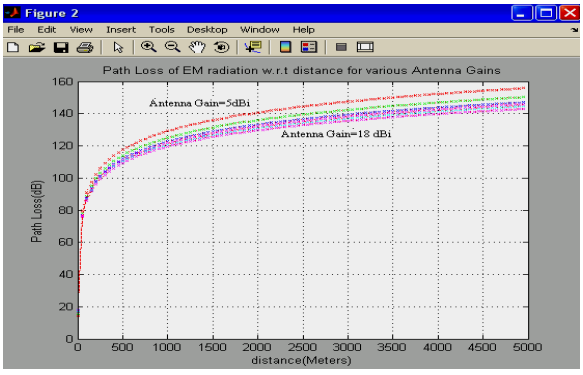

Figure10- Path loss w.r.t. various antenna gains

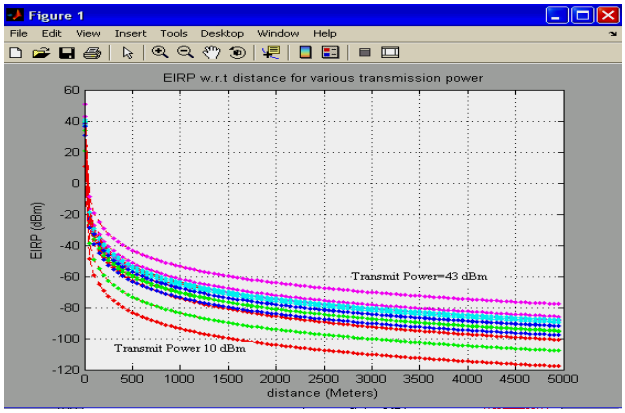

Figure11- EIRP w.r.t distance for various Transmission Power

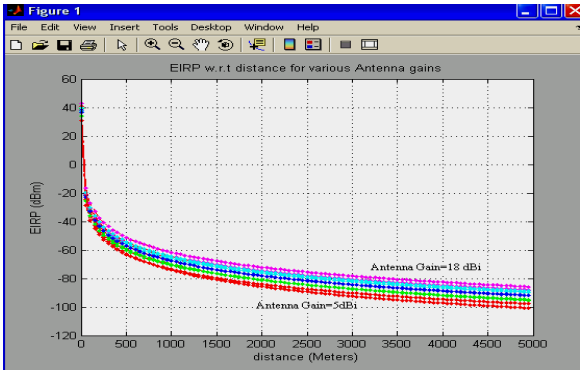

Figure12-EIRP w.r.t. distance for various antenna gains

VI. CONCLUSION

This paper was concern with practical measurement of cell tower radiation and QoS along with realization of compliance distance for various antenna gain and bands. It was observed that operators were able to manage radiation level 1/100 to 1/1000 below the recommended value while maintaining QoS. So radiation norms can be further strengthened i.e. recommended power density at compliance distance may be f/2000 or less then it. It was observed that compliance distance for 6 carriers with 18dBi antenna gain and 43dBm EIRP was near about 12 meters from the tower and for 36 carriers this value reaches to 57.5 meter. It was also observed that compliance distance varies with antenna gain, transmitting power, frequency etc. Frequency hopping did not put any influence on compliance distance. The designed model can further be utilized in future for auditing of BTS.

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