2020

Consultation Paper

Permitting Signal Boosters (Repeaters) for Improving Indoor Coverage

Pakistan Telecommunication Authority

The stake holders are requested to respond back to this consultation by **<u>31st October, 2020.</u>** All responses should be sent electronically to repeater-regulations@pta.gov.pk with a copy to Director General (Strategy and development) PTA HQs at imad@pta.gov.pk

The comments received after **<u>31st October, 2020</u>** would not be considered.

PTA assures the stakeholder that all the comments received would be duly analyzed and would be considered while preparing the framework for regulatory measures and solutions.

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. Background:

A reliable indoor service is becoming an increasingly important component for consumers of mobile service, as data consumption in indoor environments is already at significant levels and predicted to rise exponentially over the next few years. Indoor coverage at work and home is regularly cited as the number one reason for network-related churn and consumer attitude surveys highlighted that consumers with poor mobile service at home have churn rates much higher than average.

The mobile licenses have no explicit binding for provision of indoor coverage. Also the Building Entry Loss (BEL) is one of the challenging factor for today's modern buildings to be covered by wireless signals. However, the current pandemic of COVID-19 has enhanced the need of good indoor coverage to access online education classes as well as work from home. This has resulted into growing service quality complaints.

Signal Boosters, also known as Repeaters represent a cost-effective means of improving wireless infrastructure. Mobile voice and mobile broadband services are increasingly important to consumers.

This document sets out the technical requirements that need to be met for mobile phone repeaters to be lawfully used by consumers on a license exempt basis whilst ensuring they are not likely to be a source of undue interference or have an adverse effect on technical quality of service.

It should be noted that, until Technical regulations for mobile phone repeaters come into force, the use of mobile phone repeaters, apart from those supplied and operated under the control of a Cellular Mobile Operator (CMO), will remain unlawful.

2. User Demand for In-building Solutions:

The different types of users and their demand for various types of in-building solutions is shown in Annex-A.

For Home Users, Small Offices, out of box solutions are available which are both convenient and risky. Technical vetting isn't a priority for such consumers and cost drives the selection. Availability of good quality products is essential to ensure Cellular Mobile Operators (CMOs) network isn't affected and this can be done by streamlining the solution and approving only technically selected vendor products to be sold in the local market. Along with product standardization, professional installation is also recommended.

For Multistory buildings, if there is coverage issue only, CMOs may deploy the repeater solution in collaboration with building owner. But if capacity needs to be enhanced as well then a proper In-building solution including active components may be needed. Just like electrical wiring is part of a building and the owner is responsible for its deployment, the building owner should fund the provision of distributed antenna system installation in the building. PTA is in the process of developing in-building codes for telecom system deployment.

2. Available Indoor Solutions:

The types of solutions that exist in the market and the selection of these solutions are mainly influenced by the type of users and their coverage requirements. Different type of In-Building Solutions are shown in Annex-B. Signal Booster / Repeater is one of the available solutions.

If there are coverage holes at a specified location housing multiple structures, then the best option is to deploy outdoor micro multi operator sites / Small Cells.

4. Types of Repeater Solution:

The repeater solutions that need to be considered to address the issue of degraded indoor service quality are as under:

(a) Broadband (Wideband) Repeaters: Broadband repeaters are generally not recommended as they cause more issues by amplifying interference and noise within the spectrum and creating optimization challenges for CMOs. FCC, however, has recently permitted deployment of Broadband repeaters at consumer premises.

(b) Band-specific Repeaters: CMO specified pre-configured band repeaters can be permitted.

(c) Multi-Operator Repeaters: The issue here is that since there are multiple CMOs operating in Pakistan, there are multiple operators' SIMs used by one's family members. Most of the problem areas are common for each CMO based on the location and type of construction so consumer within those locations will face issues for all CMOs. If repeaters are sold for CMO specified configurations then this would mean that they will need to pay for (2) to (3) devices on average within the same household which is impractical. The option of multi CMO repeaters (sub bands within each band) can be further explored to support at least (2) CMOs per device but such devices are expensive which increases cost for all involved. Then again in such categories, configurable repeaters are needed in order to configure (2) CMOs on each device based on consumer requirements. Mechanism needs to be finalized in such situations as to who will take ownership and who will be customer interface.

(d) Enterprise Solutions: For enterprises, multiband multi operator wireless repeaters can be deployed to facilitate their buildings (residential / corporate). But a licensing policy needs to be put in place which facilitates the willing private investors to invest in repeaters and indoor or outdoor Distributed Antenna System (DAS). These are coverage driven solutions. If capacity is to be enhanced then Base Transceiver Station (BTS) resources needs to be brought into the mix.

5. Challenges posed by Repeaters:

While CMOs try to provide blanket coverage to population centers, coverage gaps exist within and at the edge of service areas which can lead to dropped calls, reduced data speeds, or complete loss of service. Repeaters can bridge these gaps and extend coverage at the fringe of service areas. Repeaters are particularly useful in rural and difficult-to-serve indoor environments, such as office buildings and hospitals.

Distinct from the majority of other in-building solutions, repeater solutions do not require the user to have a broadband connection. This makes them the only solution for areas where there is no broadband connection but a reasonably good outdoor cellular signal. However, there are some technical challenges associated with Repeaters, presented in Annex-C, due to which import, sale and use of repeaters is prohibited in Pakistan.

6. Regulatory Measures taken by UK & USA:

Countries have adopted diverse approaches to tackle the issues related to Mobile Phone Amplifiers and mitigating its interference. United State of America (USA) and United Kingdom (UK) have allowed use of Signal Repeaters / Amplifiers by the consumers while ensuring compliance with technical, operational, and registration requirements. The details are presented in Annex-D.

7. Technical Standards:

7.1 Operation of Mobile Phone Repeater:

(1) Compliance of ETSI Standards: A Mobile Phone Repeater shall operate, if it is compliant of ETSI Standards EN 303 609, EN 301 908-11 and EN 301 908-15, and any revisions to those standards.

(a) EN 303 609: Global System for Mobile communications (GSM); GSM Repeaters; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU

(b) EN 301 908-11: Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks; Part 11: Harmonized EN for IMT-2000, CDMA Direct Spread (UTRA FDD and EUTRA FDD) (Repeaters) covering the essential requirements of article 3.2 of the R&TTE Directive.

(c) EN 301 908-15: IMT cellular networks; Harmonized Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 15: Evolved Universal Terrestrial Radio Access (E-UTRA FDD) Repeaters.

(2) Interference Protection: A Mobile Phone Repeater shall operate, if it avoids any harmful interference to primary users of frequency bands of operations of mobile services in Pakistan, Azad Jammu & Kashmir and Gilgit Baltistan by complying with following:

(a) Network Protection Standards (as mentioned in Section 7.2)

(b) All applicable technical standards for the frequency band(s) of operation, as prescribed by relevant regulatory / standardization bodies, including but not limited to:

(i). Frequency Tolerance,
(ii). Effective Radiated Power Limits,
(iii). Emission Limitations for Cellular Equipment,
(iv). Power Limits; and
(v). Emission Masks, etc.

(3) Registration: Prior to installation / operation of Mobile Phone Repeater, the customer shall:

(a) Register the Mobile Phone Repeater with the CMO providing service to the customer. Following information needs to be provided: Personal Details, Location Coordinates / Address,

(b) Provide consent that in the event of interference, customer is liable to uninstall the Mobile Phone Repeater.

(4) The customer will only operate the Mobile Phone Repeater with approved antennas, cables, and/or coupling devices as specified by the manufacturer of the Mobile Phone Repeater;

(5) The customer may not deactivate any features of the Mobile Phone Repeater which are designed to prevent harmful interference to wireless networks. These features must be enabled and operating at all times the Mobile Phone Repeater is in use;

(6) A Mobile Phone Repeater shall operate on a secondary, non-interference basis to primary services licensed for the frequency bands of their transmission, and to primary services licensed for the adjacent frequency bands that might be affected by their transmissions.

(a) The operation of Mobile Phone Repeater must not cause harmful interference to the communications of any primary licensed service.

(b) Upon request of a representative of the Authority or Board detection of harmful interference, the customer of Mobile Phone Repeater must cooperate in:

(i) Determining the source of interference, and
(ii) If necessary, deactivate and handover the faulty Mobile Phone Repeater immediately to the representative of the Authority or Board, or replace the faulty Repeater with Authority Certified Repeater.
(iii) In case of non-cooperation, action under Section 31 of the Act shall be initiated against the customer.

7.2 Network Protection Standards:

(1) <u>Features to prevent harmful interference:</u> All Mobile Phone Repeaters must have appropriate features incorporated to prevent harmful interference to mobile networks including but not limited to following:

(a) <u>Frequency Bands:</u> Mobile Phone Repeaters must be designed and manufactured such that they only operate on the frequencies used for the provision of mobile services in Pakistan, Azad Jammu & Kashmir and Gilgit Baltistan.

(b) Self-Monitoring: Mobile Phone Repeaters must automatically self-monitor their operation to ensure compliance with applicable noise and gain limits and either self-correct or shut down automatically if their operation exceeds those parameters.

(c) Anti-Oscillation: Mobile Phone Repeaters must be able to detect and mitigate any unintended oscillations in uplink and downlink bands (such as those which may result from insufficient isolation between the antennas).

(d) Power Down: Mobile Phone Repeaters must automatically power down or cease amplification as they approach any affected base station.

(e) Interference Avoidance for Wireless Subsystem: Mobile Phone Repeaters using unlicensed frequency bands for wireless transmissions between donor and server subsystems for their internal operation must employ interference avoidance methods to prevent interference transmitted into other spectrum bands.

(2) Technical Requirements: A Mobile Phone Repeater must meet following technical requirements.

(a) Automatic Standby:

(i) Indoors Use: When the repeater is no longer serving an active device connection it must, after no more than 5 minutes reduce any uplink noise power to no more than −70 dBm/MHz EIRP.

(ii) Vehicular Use: When the repeater is no longer serving an active device connection it must, after no more than 5 minutes, reduce any uplink noise power to no more than −70 dBm/MHz TRP.

(b) Gain Control:

(i) A Mobile Phone Repeater must have automatic gain control to protect against excessive input signals that would produce output power emissions that would cause interference to a mobile base station.

(ii) A Mobile Phone Repeater must adjust its gain in accordance to the strongest signal present in the downlink band of operation so that the noise of the repeater cannot reach the base station.

(iii) Gain of a Mobile Phone Repeater must be adjusted so that the uplink noise does not exceed -103 dBm /MHz – RSSI. Where RSSI is the measure of Received Signal Strength (dBm) per band of operation at the port of the device.

(iv) A Mobile Phone Repeater must power off if it can no longer meet this specification.

(c) Maximum Gain

(i) Indoors Use: The uplink and downlink system gain of a repeater referenced to its input and output antennas, shall not exceed 100 dB.

(ii) Vehicular Use: The uplink and downlink system gain of a repeater, referenced to its input and output antennas, shall not exceed 20 dB.

(d) Noise Figure:

(i) Mobile Phone Repeater Noise Figure shall not exceed 7 dB.

(e) Single Operator Configuration:

(i) The amplified frequencies shall be limited to those licensed to a single mobile network operator.

(ii) The equipment may be re-configured to alternate frequencies, but may only operate using frequencies licensed to a single operator when configured.

(f) Anti-Oscillation:

(i) Oscillation detection and mitigation must occur within 0.3 seconds in the uplink band and (1) second in the downlink.

(ii) In case of oscillation, the repeater must continue this mitigation for at least one (1) minute before restarting.

(iii) After five (5) such restarts, the repeater must not resume operation until manually reset.

(g) Transmit Power / Power Density:

(i) The transmit power is limited to the maximum permitted power of a mobile handset in the uplink and 17 dBm (0.05 Watts) in the downlink.

(ii) In case of Indoors use, a Mobile Phone Repeater must comply with Transmit Power / Power Density requirement for following frequency bands of operation:

Band	Technology	Maximum Uplink	Maximum Downlink
800	Technology Neutral	23 dBm EIRP	PSD 10 dBm/5 MHz EIRP
			Total 17 dBm EIRP
900	GSM	33 dBm EIRP	10 dBm EIRP
1800	GSM	30 dBm EIRP	10 dBm EIRP
900, 1800 & 2100	3G	24 dBm EIRP	PSD 10 dBm/5 MHz EIRP
			Total 17 dBm EIRP
900 & 1800	LTE	23 dBm EIRP	PSD 10 dBm/5 MHz EIRP
			Total 17 dBm EIRP
2100	Technology Neutral	24 dBm EIRP	PSD 10 dBm/5 MHz EIRP
			Total 17 dBm EIRP

(iii) In case of Vehicular use, a Mobile Phone Repeaters must comply with Transmit Power/ Power Density requirement for following frequency bands of operation:

Band	Technology	Maximum Uplink	Maximum Downlink
800	Technology Neutral	23 dBm TRP	PSD 10dBm/5MHz TRP
			Total 17dBm TRP
900	GSM	33 dBm TRP	10dBm TRP
1800	GSM	30 dBm TRP	10dBm TRP
900, 1800 & 2100	3G	24 dBm TRP	PSD 10dBm/5MHz TRP
			Total 17dBm TRP
900 & 1800	LTE	23 dBm TRP	PSD 10dBm/5MHz TRP
			Total 17dBm TRP
2100	Technology Neutral	24 dBm TRP	PSD 10dBm/5MHz TRP
			Total 17dBm TRP

(h) Intermodulation Attenuation: The maximum level of intermodulation product shall not be greater than:

(i) -36 dBm in the frequency band less than 1 GHz

(ii) -30 dBm in the frequency band more than 1 GHz

(i) Radiated Spurious Emission: The effective radiated power shall not exceed:
   (i) -36 dBm in the frequency band less than 1 GHz
   (ii) -30 dBm in the frequency band more than 1 GHz

(j) Out of Band Gain: Following limits will apply to Out of Band Gain:
   (i) 50 dB at 400 kHz offset and greater
   (ii) 40 dB at 600 kHz offset and greater
   (iii) 35 dB at 1MHz offset and greater
   (iv) 25 dB at 5MHz offset and greater

7.3 Mobile Phone Repeater Certification Requirements

(1) Mobile Phone Repeater Certificate, subject to fulfillment of technical requirements, may be issued to any person, class of persons, company or corporation.
(2) Application for Mobile Phone Repeater Certification shall be made according to procedure prescribed in "Type Approval Regulations, 2004" and "Type Approval Technical Standards Regulations, 2017", and subsequent amendments thereafter
(3) The application for certification must satisfy the Authority that the Mobile Phone Repeaters' features designed to prevent harmful interference and protect wireless networks cannot be easily defeated and must be enabled at all times.
(4) Mobile Phone Repeater Certificate may be canceled upon breach of any of the technical requirements.
(5) Submission of Declaration of Conformity from manufacturer stating the standard complied by the device.
(6) Submission of EMC/EMI Test reports.

8. Questions for Consultation:

PTA believes that good indoor coverage is essential in order to facilitate, among other things, online education and work from home in the era of COVID-19 pandemic.

Mobile phone repeaters amplify signals between a mobile phone and a network operator's base station and can enhance coverage in situations where the signal is weak. Their use by consumers is currently unlawful, as the types of wideband repeaters that we come across today can cause undue interference or other adverse effects to mobile services for other consumers. **The only exception is if the repeaters are supplied and operated under the control of a CMO.**

Q1. Should PTA permit the use of Mobile Phone Repeaters by general public?

Q2. Referring to Section-4 of the document, which types of Mobile Phone Repeaters shall be permitted and why? Should PTA permit only Band Specific Repeaters or other types as well, such as Wideband Repeaters? If so, how to mitigate the interference issue associated with them.

Q3. If wideband repeaters are not to be permitted, what is the best way to accommodate users of different CMOs present in a single location?

Q4. Should there be a requirement for registration of Mobile Phone Repeater with CMOs. In either case, yes or no, please give justification.

Q5. Do you agree with the conditions specified for Mobile Phone Repeater Registration in section 7.1 (3)? If not, kindly suggest otherwise.

Q6. If registration of Mobile Phone Repeaters should be required then suggest a process on how it should be done.

Q7. Should there be a technical survey conducted by CMO in order to check the network performance in the affected area prior to permitting repeater installation?

Q8. Should repeater installation be allowed only through professional installers (CMOs) or anyone should be able to install it.

Q9. Should the sale of repeaters be permitted only through CMO franchises or other retail channels may be allowed as well? In either case, please justify with reasons.

Q10. Should PTA permit only static Repeaters for in-building installations only or for Vehicular Use as well (such as buses, trains, cars, etc.)?

Q11. Should there be a requirement for identifying the type approved repeater models through a physical label? If so, who should label them - the vendors or the CMOs.

Q12. Do you agree with the proposed technical requirements of Network Protection Standard or otherwise? Do you propose any change in the technical requirement? Please justify your answer with reasons.

9. Definitions:

"Authority" means the Pakistan Telecommunication Authority;
"Board" means Frequency Allocation Board;
"Mobile Phone Repeater" means a wireless telegraphy station or wireless telegraphy apparatus which amplifies the radio signals carried over a GSM system, a LTE system and a UMTS system;
"dBm" means decibels of power referenced to one milliWatt;
"Downlink Bands" means the frequency bands 869-894MHz, 925-960 MHz, 1805-1880 MHz and 2110-2170 MHz;
"Uplink Bands" means the frequency bands 824-849MHz, 880-915MHz, 1710-1785MHz and 1920-1980MHz;
"ETSI" means the European Telecommunications Standards Institute;
"EIRP" means the Effective Isotropic Radiated Power that is the measured radiated power in a single direction;
"GSM system" means an electronic communications network that complies with standards EN 301 502(**3**) and EN 301 511(**4**) published by ETSI for the Global System for Mobile Communications (also known as GSM);
"Indoors" means inside premises which— (i) have a ceiling or a roof; and (ii) except for any doors, windows or passageways, are wholly enclosed;
"LTE system" means an electronic communications network that complies with standards EN 301 908—1(**5**), EN 301 908—13(**6**) and EN 301 908—14(**7**) published by ETSI for the Long Term Evolution telecommunication system (also known as LTE);
"Repeater Certification" or "Certificate" means the certification that a type/model of Mobile Phone Repeater conforms to the technical standards prescribed by the Authority;
"TRP" means Total Radiated Power that is a measure of how much power is radiated by an antenna when the antenna is connected to an actual radio (or transmitter);
"UMTS system" means an electronic communications network that complies with standards EN 301 908—1, 301 908—2(**8**) and EN 301 908—3(**9**) published by ETSI for the Universal Mobile Telecommunications System (also known as UMTS);
"Vehicular" means a mechanically propelled vehicle intended or adapted for use on roads.

10. Annexures:

Annex-A: Available Indoor Solutions.
Annex-B: Types of Users & their Demand Analysis.
Annex-C: Technical Challenges of Repeaters.
Annex-D: Regulatory Measures taken by UK & USA.
Annex-E: Sample Labelling Requirements mandated by FCC.

ANNEX-A: Types of Users and their Demand Analysis

Different types of users and their demands for choosing in-building solutions is shown the following table:

TYPE	USERS DEMANDS
Home Users	▪ BETTER IN-HOME COVERAGE, IMPROVED DATA RATES THROUGH A LOW COST SOLUTION ▪ QUICK AND EASY INSTALLATION AND IDEALLY JUST NEED POWER ▪ SAFE SOLUTION AROUND THE FAMILY ▪ SUPPORT MULTIPLE OPERATORS BUT NOT ESSENTIAL
Small Office	▪ HIGHER CAPACITY REQUIREMENTS THAN HOME USERS ▪ LESS CHANCES OF REPLACEMENT OF FIXED LINE CONNECTION ▪ CAN BE LOCKED INTO A SINGLE OPERATOR THROUGH COMPANY MOBILE CONTRACT
Multistory Buildings	▪ REQUIRES HIGHLY RELIABLE COVERAGE AND CAPACITY ACROSS ALL OF BUILDING ▪ ISSUE OF COST SENSITIVITY BUT NOT AS MUCH AS IN CASE OF HOME USERS AND SMALL OFFICES ▪ HAVE A LARGER BUDGET AND WILLINGNESS TO TRADE OFF HIGHER PRICE FOR QUALITY OF SERVICE DELIVERED ▪ LIKELY TO TOLERATE A MORE COMPLEX INSTALLATION ▪ BUILDING MAY BE USED TO BEING LOCKED INTO A SINGLE OPERATOR THROUGH COMPANY MOBILE CONTRACT
Public Building / Campus	▪ REQUIRE RELIABLE COVERAGE AND HIGH DATA RATES AS THIS FACTOR MAY DIFFERENTIATE THEM FROM OTHER VENUES ▪ MULTI OPERATOR SUPPORT IS ESSENTIAL AND VERY HIGH CAPACITY REQUIREMENTS ▪ ISSUE OF COST SENSITIVITY BUT MAY BE WILLING TO MAKE THE INVESTMENT TO STIMULATE BUSINESS AND KEEP UP WITH COMPETITORS ▪ CHANCES OF INCLUDING SOME OUTDOOR AREAS IN THE SOLUTION

ANNEX-B: Types of Indoor Solutions

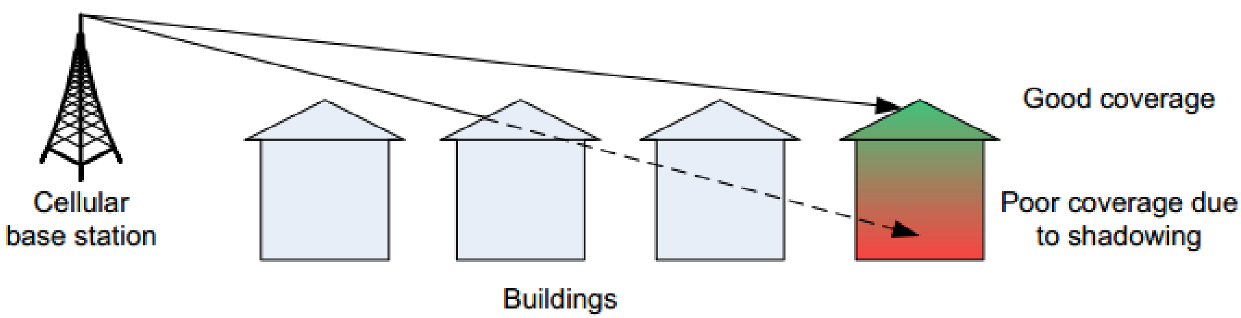
Solution types and their selection is influenced mainly by coverage requirements.

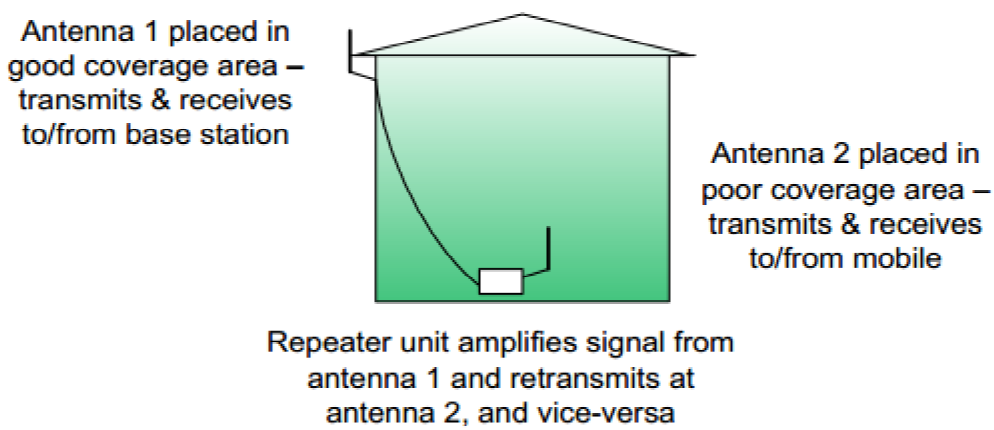
TYPE	SOLUTION FEATURES
Wi-Fi	▪ POPULAR OPTION FOR IMPROVING INDOOR MOBILE SERVICES ▪ **REQUIRES BROADBAND CONNECTION** ▪ LIMITED TO PROVIDING DATA SERVICES
Carrier Wi-Fi	▪ CARRIER WI-FI IS A NEW CATEGORY OF WI-FI ▪ **REQUIRES BROADBAND CONNECTION** ▪ INCLUDES FEATURES FOR ROAMING BETWEEN CELLULAR & CARRIER WI-FI NETWORK
Signal Boosters / Repeaters	▪ CAN POTENTIALLY CAUSE HARMFUL INTERFERENCE ▪ COST EFFECTIVE MEANS OF IMPROVING WIRELESS INFRASTRUCTURE ▪ OPERATOR DEPLOYED REPEATERS ARE STILL WIDELY USED FOR LARGE BUILDINGS ▪ SIGNAL REPEATERS OF ALL TYPES RELY ON A GOOD OUTDOOR SIGNAL TO BOOST INTO THE TARGET BUILDING
Femto Cells	▪ LOW COST CELLULAR BASE ▪ **REQUIRES BROADBAND CONNECTION** ▪ PROVIDE ALL CELLULAR SERVICES INCLUDING VOICE AND SMS, ▪ USUALLY PROVIDED AS PART OF THE USER'S MOBILE SUBSCRIPTION.
Pico Cells	▪ SIMILAR TO FEMTO CELLS ▪ **REQUIRES BROADBAND CONNECTION** ▪ COVERS LARGER AREAS AND TARGET BIGGER SME BUILDINGS
Distributed Antenna Systems	▪ INFRASTRUCTURE OF CABLES, AMPLIFIERS AND ANTENNAS ▪ DISTRIBUTE MOBILE SIGNALS IN ANALOGUE FORM THROUGHOUT BUILDING ▪ **OBTAINS SERVICE FROM A DEDICATED HIGH CAPACITY BASE STATION, A REPEATER OR SMALL CELLS** ▪ COSTLY TO PLAN AND INSTALL ▪ ONLY SUITABLE FOR LARGE HIGH CAPACITY BUILDINGS OR CORPORATE BUILDINGS ▪ INSTALLED IN BUILDING WHERE THE VALUE OF THE OVERALL ACCOUNT TO AN OPERATOR CAN JUSTIFY THE HIGH CAPITAL INVESTMENT IN THE INFRASTRUCTURE, ▪ ALLOW RELATIVELY STRAIGHTFORWARD SUPPORT FOR MULTIPLE OPERATORS

ANNEX-C: Technical Challenges of Repeaters

Background:

Repeaters are used in practice to enhance coverage by amplifying and re-transmitting mobile signals to improve coverage in areas where it is poor. There are sound technical reasons why the coverage provided by the main network will not penetrate certain areas. The walls of buildings, metallization of windows for thermal reasons, and the use of underground spaces all attenuate the signals between mobile and base station. This attenuation of the signal will eventually lead to loss of connection at times.





The above figure shows an urban or suburban setting where good reception in the lower part of one building is prevented by shadowing from other buildings in the area. Poor coverage can also occur in other situations, for example:

• In remote areas far from the nearest base station.

• In buildings where penetration losses are high e.g. old stone buildings or newer buildings with metallized glass to meet the latest building requirements for insulation.

In each case a repeater can still be the solution and will work in the same way as above. The antenna details will vary to suit the particular situation. In remote or hilly locations the reception outdoors may be poor and so Antenna 1 may be a high gain antenna such as a Yagi.

Challenges:

Repeaters take the whole of a mobile band, amplify and re-transmit it. Signal strengths and noise levels across the whole band will be increased, meaning that all networks operating in that band are affected. Fixing a coverage problem for a small number of users can result in degrading coverage for a much larger number of users.

There are several different mechanisms by which a repeater could interfere with the operation and performance of the mobile network.

1. Raising the noise floor on the uplink signal
2. Raising the noise floor on the downlink signal
3. Blocking (overloading) the base station receiver
4. Disrupting the uplink power control
5. Oscillations and spurious emissions
6. Distortion or delay of the signals

1. Raising the noise floor on the uplink signal

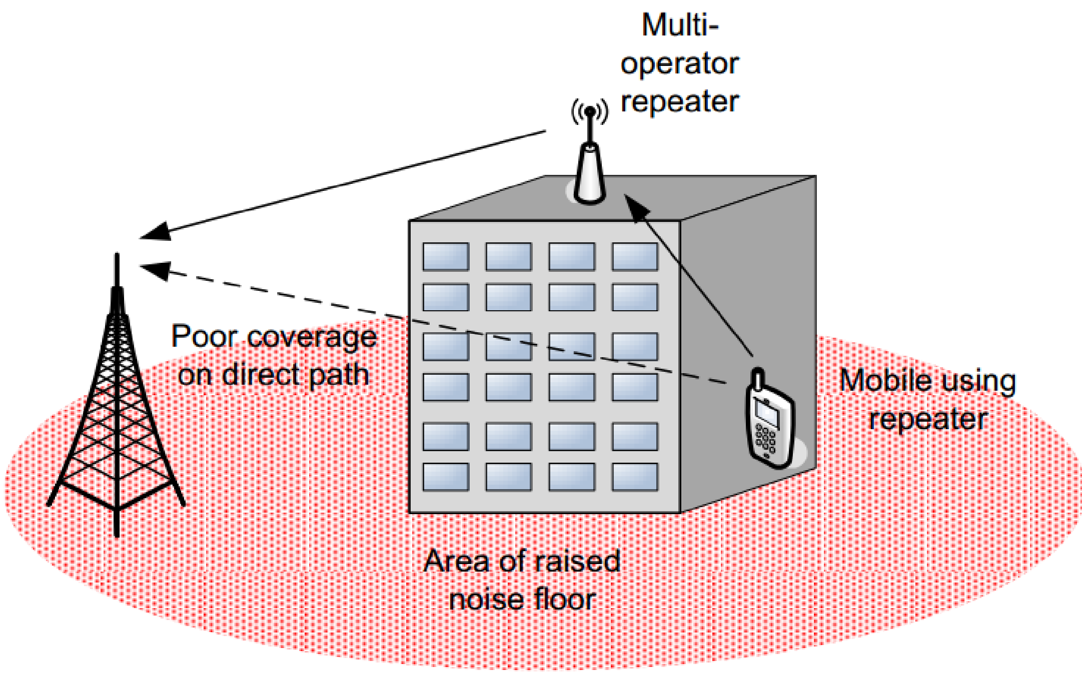
The repeater will transmit not only the wanted signal but wideband noise. This is because, like any electronic device, there is thermal noise inherent in its components. The combination of the amplifier gain and noise figure means that the noise floor at the output could plausibly be 80dB above thermal noise. In addition any noise at the input from external sources will be amplified along with the wanted signal.

If there is a relatively small path loss from the repeater to the base station then the noise transmitted by the repeater can be above the sensitivity level of the base station's receiver. In this case the base station's effective sensitivity is reduced.

For mobiles at the edge of the cell, already operating at the upper end of their power control range, the uplink connection will be lost. The user will see the symptom as a dropped or blocked call even if their mobile shows there is network coverage. The mobile is at the cell edge so the interference mostly affects mobiles that are some distance away from the repeater. The operator will see a worse than expected signal to noise ratio (SNR) in their network monitoring system.

In 3G and 4G systems the data rates are variable for each link and in total. Increasing the noise floor reduces the SNR. This causes an increase in bit errors that in turn will cause the radio link control to increase the mobile's power. If it is not possible to increase the mobile's power, either because it is at maximum already or for load balancing reasons, then the data rate will be reduced. The effect of the repeater noise is therefore to reduce the capacity of the cell even if the connection is not dropped.

Same Network Interference occurs where the outdoor coverage is good but there is a high penetration loss to the user's location. This may be at the center of a large building such as an office block or hotel with many rooms; it may be the basement floors of a shopping center or multi-story car park. **In these cases the wanted base station may be quite close to the repeater, and so is affected by the raised noise floor. This reduces the coverage area for other mobiles that are on the same cell but outside the repeater's coverage.**



2. Raising the Noise Floor - Downlink

The mechanism for raising the noise floor in the downlink is similar in nature to that in the uplink, except that it is the mobile's receiver that is affected. As the repeater's downlink output power is a lot less than a macro base station, it is only mobiles near to the repeater that will be affected.

The wanted output signal is amplified from a weak level to a much stronger level, that being the purpose of the repeater. For a multi-operator repeater the noise level is raised for all mobiles in the vicinity, but so is the wanted signal. A mobile that is currently receiving a good signal may suffer a reduction in SNR. However there is unlikely to be a significant interference problem from this effect. Mobiles that are currently receiving a weak signal are likely to benefit more from the increase in wanted signal than they suffer from the increase in noise - this is the purpose of the repeater.

3. Base Station Receiver Blocking

The repeater will transmit the signal from the mobile after amplifying it. If the repeater is near to a base station and at full gain then the signal at the input of the base station's receiver will be at a high level.

If the level is too high then the receiver will be overloaded and it the reception of other mobiles will be degraded or stopped entirely. This process is known as blocking.

In practice GSM, UMTS and LTE systems all use uplink transmitter power control (ULPC). This is particularly important in UMTS due to the use of code division multiple access (CDMA). The base station measures the signal level that it is receiving from a mobile and continuously instructs the mobile to increase or decrease its transmitter power. This maintains the signal level at the base station at its optimum level. An increase in the path loss to the mobile will result in the mobile being instructed to raise its power, until it is at maximum power. Any further increase in path loss will cause the mobile to go out of coverage.

If the repeater gain is fixed then the ULPC function still works correctly. In this case the ULPC will adjust the mobile's transmit power as required and the repeater will not cause blocking.

4. Power Control

If changes in the mobile's transmit power are not carried through the repeater then the ULPC breaks down, causing blocking as described above. There are two apparent routes by which this may happen:

- The repeater is at its maximum power level. This has the same effect as the mobile reaching its maximum power - the mobile goes out of coverage
- The repeater employs gain control that maintains a steady output power on the uplink. This will defeat the ULPC and is likely to reduce the capacity and/or coverage of the cell

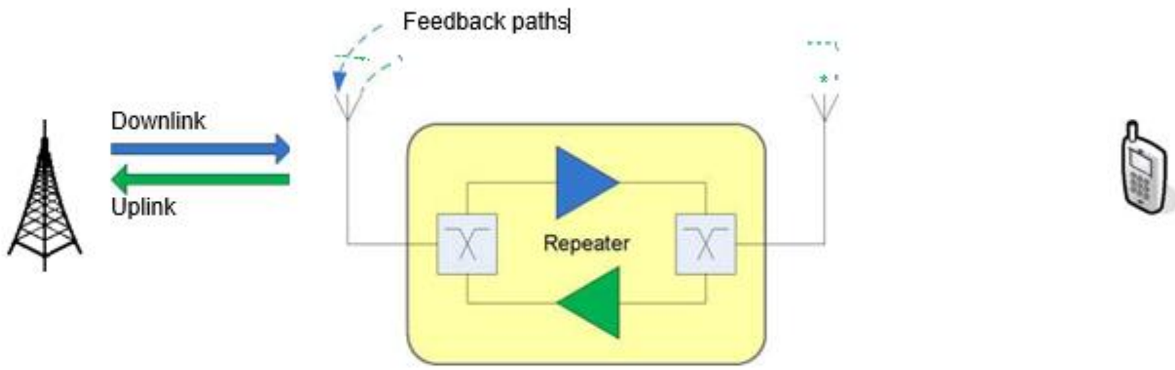
3G systems are particularly sensitive to a failure of ULPC. If a mobile's power is too low it will be dropped; if it is too high it will reduce the capacity of the cell for other mobiles.

The potential for interference to the cell therefore depends on the gain control, if any, that is used. Maintaining a constant gain is not a problem, maintaining a constant output power is likely to cause interference.

5. Oscillation and Spurious Emissions

At its simplest a repeater consists of two amplifiers, one for the uplink and one for the downlink. Diplexers are fitted to allow the output of one amplifier and the input of the other to use the same antenna. The main signal path for the downlink is from the base station to one antenna, through the downlink amplifier, and from the second antenna to the mobile. The reverse path applies to the uplink.

However there exists another path that is unintended - the path between the two antennas. This acts as a feedback path from the output to the input of each amplifier



If the loss on the feedback path is less than the gain through the repeater then it will oscillate. The oscillation will occur in the operating frequency band and will be at the repeater's saturated output power. The effect on a base station or mobile using the oscillation frequency is that the repeater will act as a jamming transmitter.

Many of the available repeaters have gains of over 50dB, which is a plausible path loss between antennas that are within a few meters of each other. For this reason, some repeaters include anti-oscillation features. Details are not disclosed but it is believed that these detect the feedback condition and reduce the gain as required to maintain stability.

A similar effect is that of spurious emissions. These are signals that are generated internally within the repeater from various sources. They could be at any frequency but those within the operating band are likely to be amplified and so cause greater levels of interference.

6. Distortion and Delay

The repeater will not only amplify the wanted signals, in any real system it will also delay and distort them to some extent. The receivers in the mobile and base station can tolerate a certain amount of distortion without a problem, but excessive distortion will cause bit errors leading to a lowering of quality of service. The effects will be the same as for high noise levels: dropped or blocked calls, and reduced data rates. This will occur even when the receiver is picking up a strong signal. The distortion in the repeater is usually greatest when the signal level is high.

Another symptom of distortion is power being spread into the channels immediately above and below the main signal - the adjacent channels. This will raise the noise level in the adjacent channels and so increase the likelihood of interference to any base stations or mobiles operating on those channels.

The delay through the repeater is mostly due to the filtering and signal processing rather than the amplifiers themselves. There is an inherent delay in both downlink and uplink paths anyway due to the speed of propagation and the distance between the mobile and base station. A distance of 300m gives a delay of 1 gs. A cellular mobile system is designed to cater for variable delays in the signal path as the mobile moves around. Different standards have different limits on round trip time (the time for the radio signal to travel from base station to mobile and back again) but they equate to a maximum range that is usually tens of km. Adding delay in a repeater will take up part of this maximum round trip time and so reduce the maximum range.

For most simple repeaters the delay is specified at <0.5gs one-way. This means it reduces the cell radius limit by no more than 150m. In practice the cell is nearly always limited by path loss to a lower radius than the timing limit and a reduction of 150m is unlikely to change this. The delay in the repeater is therefore unlikely to have an effect on cell coverage.

Smart repeaters may have longer delays due to the signal processing and more demanding filtering involved. A 5gs one-way delay will reduce the cell's maximum range by 1.5km. Unlike the noise problem, this range reduction affects only those mobiles using the repeater. Those operating directly with the base station are unaffected.

ANNEX-D: Regulatory Measures taken by UK & USA

United State of America (USA) and United Kingdom (UK) has allowed use of Signal Repeaters / Amplifiers by the consumers.

United Kingdom (UK)

Office of Communications ("OFCOM"), in exercise of the powers conferred by sections 8(3) and section 122(7) of the Wireless Telegraphy Act 2006 has made **"Wireless Telegraphy(Mobile Repeater)(Exemption) Regulation 2018"** which come into force on 12th April, 2018. Prior to these Regulations, the use of mobile phone repeaters, other than those supplied directly by the Mobile Network Operators (MNOs), was unlawful. Under these Regulations, the establishment, installation and use of a mobile repeater device is exempt from the provisions of Section 8(1) of the Act where the terms, provisions and limitations in this regulation are met. Two case of usage are allowed in UK, which are **Indoor Use** and **Motor Vehicle Use**.

UK Interference Requirement 2102: OFCOM published **"UK Interference Requirement 2102"** on 27th February, 2018.

It contains the requirements for the licensing (via license-exemption) and establishment, installation and use of (i) **static mobile phone repeaters for indoor use** and (ii) **low gain mobile phone repeaters for in-vehicle use** in the specified frequency bands.

The tables in IR2102.1, IR2102.2, Table A1 and Table A2 of the document contain the relevant equipment parameters. These taken together with the 'essential requirements' detailed in Article 3.2 of Directive 2014/53/EU constitute the minimum requirements for the use of the spectrum by the repeaters within the UK. These tables specifies the frequency bands, Transmit Power/ Power Density, Channel Access and Occupation Rules (i.e. Transmit Gain Control/Maximum Permitted Gain, Automatic Standby, Anti-Oscillation, Single Operator Configuration and Noise Figure). **The deployment of 4G only repeaters is not permitted.** All repeaters must also amplify a 2G and/or a 3G signal.

IR2102.1: Minimum requirements for the use of: Static Mobile Phone Repeaters, for Indoor Use		
Mandatory (1-11)		
1	Radiocommunication Service	Mobile
2	Application	Static mobile phone repeaters for indoor use
3	Frequency band	**800** 791-821 MHz (Downlink) 832-862 MHz (Uplink) **900** 880-915 MHz (Uplink) 925-960 MHz (Downlink) **1800** 1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink) **2100** 1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)
4	Channelling	Not specified
5	Modulation/Occupied bandwidth	Not specified
6	Direction/Separation	Repeater transmit/receive
7	Transmit power/Power density	See Table A1
8	Channel access and occupation rules	**Transmit Gain Control** The uplink and downlink system gain in dB of a repeater, referenced to its input and output ports, shall not exceed BSCL–30, where BSCL (base station coupling loss) is the path loss between the base station and the repeater. Where BSCL cannot be determined, the repeater must not transmit. The uplink and downlink system gain of a repeater, referenced to its input and output antennas, shall not exceed 100 dB. The apparatus shall determine the value of BSCL by calculating the difference between the carrier power received at the repeater and the carrier power transmitted from the base station. The carrier power transmitted by the base station may be determined from the system information messages sent by the base station on its control channels.

		Automatic Standby When the repeater is no longer serving an active device connection it must, after no more than 5 minutes, reduce any uplink noise power to no more than −70 dBm/MHz EIRP.
		Anti-Oscillation Repeaters must detect and mitigate (i.e. by automatic gain reduction or shut down) any oscillations in uplink and downlink bands. Oscillation detection and mitigation must occur automatically within: • 0.3 seconds in the uplink band; and • 1 second in the downlink band. In cases where oscillation is detected, the repeater must continue this mitigation for at least one minute before restarting. After five such restarts, the repeater must not resume operation until manually reset.
		Single Operator configuration The amplified frequencies shall be limited to those licensed to a single mobile network operator. The equipment may be re-configured to alternate frequencies, but may only operate using frequencies licensed to a single operator when configured.
		Noise figure The repeater system noise figure shall not exceed 7 dB
9	Authorisation regime	Licence Exempt[1]
10	Additional essential requirements	Nil
11	Frequency planning assumptions	Not specified
Informative (12-15)		
12	Planned changes	Nil
13	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
14	Remarks	The deployment of 4G only repeaters is not permitted. All repeaters must also amplify a 2G and/or a 3G signal.
15	Notification Number	2017/509/UK

Table A1

Band	Technology	Maximum Uplink Power	Maximum Downlink power (indoor use only)
800	Technology Neutral	23 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
900	GSM	33 dBm EIRP	10 dBm EIRP
1800	GSM	30 dBm EIRP	10 dBm EIRP
900, 1800 & 2100	3G	24 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
900 & 1800	LTE & WiMAX	23 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
2100	Technology Neutral	24 dBm EIRP	PSD: 10 dBm / 5 MHz EIRP; and Total: 17 dBm EIRP
Where PSD is power spectral density			

IR2102.2: Minimum requirements for the use of: - Low gain mobile phone repeaters for in-vehicle use

Mandatory (1-11)		
1	Radiocommunication Service	Mobile
2	Application	Low gain mobile phone repeaters for in-vehicle use; no fixed installations
3	Frequency band	**800** 791-821 MHz (Downlink) 832-862 MHz (Uplink) **900** 880-915 MHz (Uplink) 925-960 MHz (Downlink) **1800** 1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink) **2100** 1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)
4	Channelling	Not specified
5	Modulation/Occupied bandwidth	Not specified
6	Direction/Separation	Repeater transmit/receive
7	Transmit power/Power density	See Table A2
8	Channel access and occupation rules	**Maximum permitted Gain** In both the Uplink and the Downlink the maximum permitted system gain, referenced between the external antenna and the input port to the cradle, is: • 21 dB in relevant frequency bands above 1 GHz; and • 15 dB in relevant frequency bands below 1 GHz.
		Automatic Standby When the repeater is no longer serving an active device connection it must, after no more than 5 minutes, reduce any uplink noise power to no more than −70 dBm/MHz TRP.
9	Authorisation regime	Licence Exempt

10	Additional essential requirements	Nil
11	Frequency planning assumptions	Not specified
Informative (12-15)		
12	Planned changes	
13	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
14	Remarks	
15	Notification Number	2017/509/UK

Table A2

Band	Technology	Maximum Uplink Power	Maximum Downlink power (in-vehicle use only)
800	Technology Neutral	23 dBm TRP	PSD 10 dBm / 5 MHz TRP; and Total 17 dBm TRP
900	GSM	33 dBm TRP	10 dBm TRP
1800	GSM	30 dBm TRP	10 dBm TRP
900, 1800 & 2100	3G	24 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
900 & 1800	LTE & WiMAX	23 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
2100	Technology Neutral	24 dBm TRP	PSD: 10 dBm / 5 MHz TRP; and Total: 17 dBm TRP
Where PSD is power spectral density			

UNITED STATE OF AMERICA (USA)

In USA, Federal Communication Commission (FCC) issued a Report and Order on 20th February, 2013, wherein the Commission amended Parts 1, 2, 20, 22, 24, 27, and 90 of its Rules to adopt new technical, operational, and registration requirements for Signal Boosters. The Rules for wireless Signal Boosters came into effect on 1st March, 2014. The new Rules created two classes of Signal Boosters i.e. Consumer Signal Boosters and Industrial Signal Boosters.

Consumer Signal Boosters have been authorized under provider licenses subject to certain requirements. Specifically, subscribers must:

- Obtain provider consent to operate the booster;
- Register the booster with their provider;
- Limit booster use to certain frequencies used for the provision of subscriber-based services;
- Use an appropriately labeled booster with manufacturer-specified antennas, cables, and/or coupling devices;
- Use a booster that meets the Network Protection Standards and is FCC certificated;
- Operate the booster on a secondary, non-interference basis and shut it down if it causes harmful interference; and
- Not deactivate any booster features that are designed to mitigate harmful interference.

Consent & Registration Mechanism: FCC issued direction for provision of consent and maintenance of registration mechanism, as:

- Wireless providers must create and maintain a registration mechanism to allow Consumer Signal Booster operators to register their devices.

- In addition, on 1st March, 2015 and 1st March, 2016, the nationwide wireless providers must make public certain information regarding their consent for their subscribers to use Consumer Signal Boosters. Specifically, these wireless providers must publicly indicate their status regarding consent for each Consumer Signal Booster which has received FCC certification.

Network Protection Standard: Consumer Signal Boosters must meet the Network Protection Standard with the following requirements:

- Comply with existing technical parameters (e.g., power and unwanted emissions) for the applicable spectrum band;
- Automatically self-monitor certain operations and shut down if not in compliance with FCC new technical Rules;
- Automatically detect and mitigate oscillations in the uplink and downlink bands;
- Power down or shut down automatically when a device is not needed, such as when the device approaches the base station with which it is communicating;
- Be designed so that these features cannot be easily defeated; and
- Incorporate interference avoidance for wireless subsystems.
- In addition, Consumer Signal Boosters must comply with current RF exposure requirements. Consumers may continue to use existing signal boosters provided they have (i) the consent of their serving provider; and (ii) register the booster with that provider.

Two Step Transition Process: FCC established a two-step transition process for Signal Boosters equipment certification:

- With the release of this Report and Order, the Commission stopped accepting applications for equipment certification of Consumer or Industrial Signal Boosters that do not comply with new Rules and ceased certification of devices that do not comply with new Rules.
- From 1st March, 2014, all Consumer and Industrial Signal Boosters sold and marketed in the United States must meet the new requirements.

ANNEX-E: Labelling Requirements by FCC

Sample labelling requirements mandated by FCC for Consumer (Homes / Small Offices) and Industrial (Multistory / Public Buildings) users are given below:

a) For Consumer Repeaters:

This is a CONSUMER device.

BEFORE USE, you **MUST REGISTER THIS DEVICE** with your wireless provider and have your provider's consent. Most wireless providers consent to the use of signal boosters. Some providers may not consent to the use of this device on their network. If you are unsure, contact your provider.

You **MUST** operate this device with approved antennas and cables as specified by the manufacturer. Antennas **MUST** be installed at least 20 cm (8 inches) from any person.

You **MUST** cease operating this device immediately if requested by the FCC or a licensed wireless service provider.

WARNING. E911 location information may not be provided or may be inaccurate for calls served by using this device.

b) For Industrial Repeaters:

WARNING. This is **NOT** a **CONSUMER** device. It is designed for installation by **FCC LICENSEES** and **QUALIFIED INSTALLERS**. You **MUST** have an **FCC LICENSE** or express consent of an FCC Licensee to operate this device. Unauthorized use may result in significant forfeiture penalties, including penalties in excess of $100,000 for each continuing violation.