Impact of new 5G network components on OOB emissions @ 23.8 GHz

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Elliot Eichen
elliot.eichen@choyu.net

Summary:

- 5G repeaters & high power 3gpp class 1 FWA (Fixed Wireless Access) chip sets were not included in interference calculations between 5G @ 24 GHz, and EESS @ 23.8 GHz leading to WRC-19 recommendations.

- Introduced in late 2019, 5G repeaters and high power FWA Tx are currently deployed in 28 GHz networks, and are expected to be deployed in substantive numbers @ 24 GHz.

- 5G repeaters and FWA transmitters will increase the interference from 5G IMT networks to EESS sounders. Under some conditions these increases may be catastrophic.

- Research, development, and deployment in wireless communications moves at ***Internet Time***, while the current ITU methodology and process for insuring spectrum co-existence was designed for ***PSTN time*** (Public Switched Telephone Networks). ***Consider alternatives***.

5G Repeaters:

5G massive MIMO
gNB antennas

Tx Downstream

Tx Upstream: WRC-19 assumed class 3 UE ~22 dBm TRP

5G Fixed Wireless
Access UE (modem)

- Analog MIMO repeaters: network (outside plant), or customer premise equipment (CPE).
- mm-wave 5G issues: cost, coverage, blocking; many access paths are NLOS (non line of sight)

5G Repeaters:

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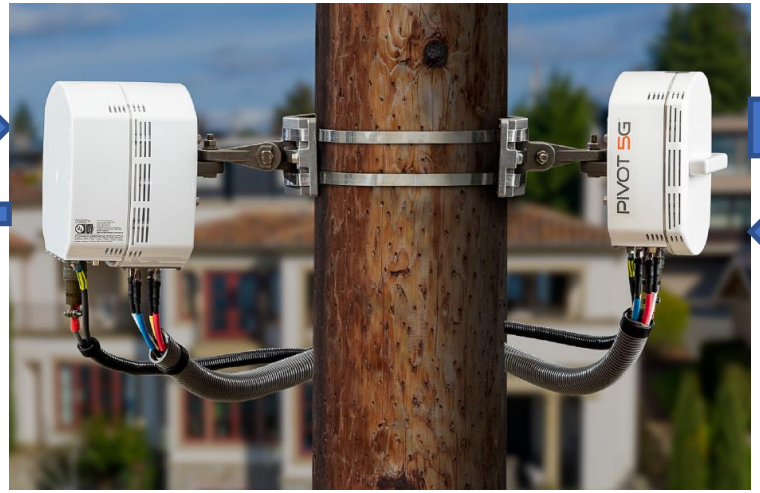
Tx downstream

Tx upstream



Amplified Tx
downstream

Tx upstream

5G Fixed Wireless
Access UE (modem)

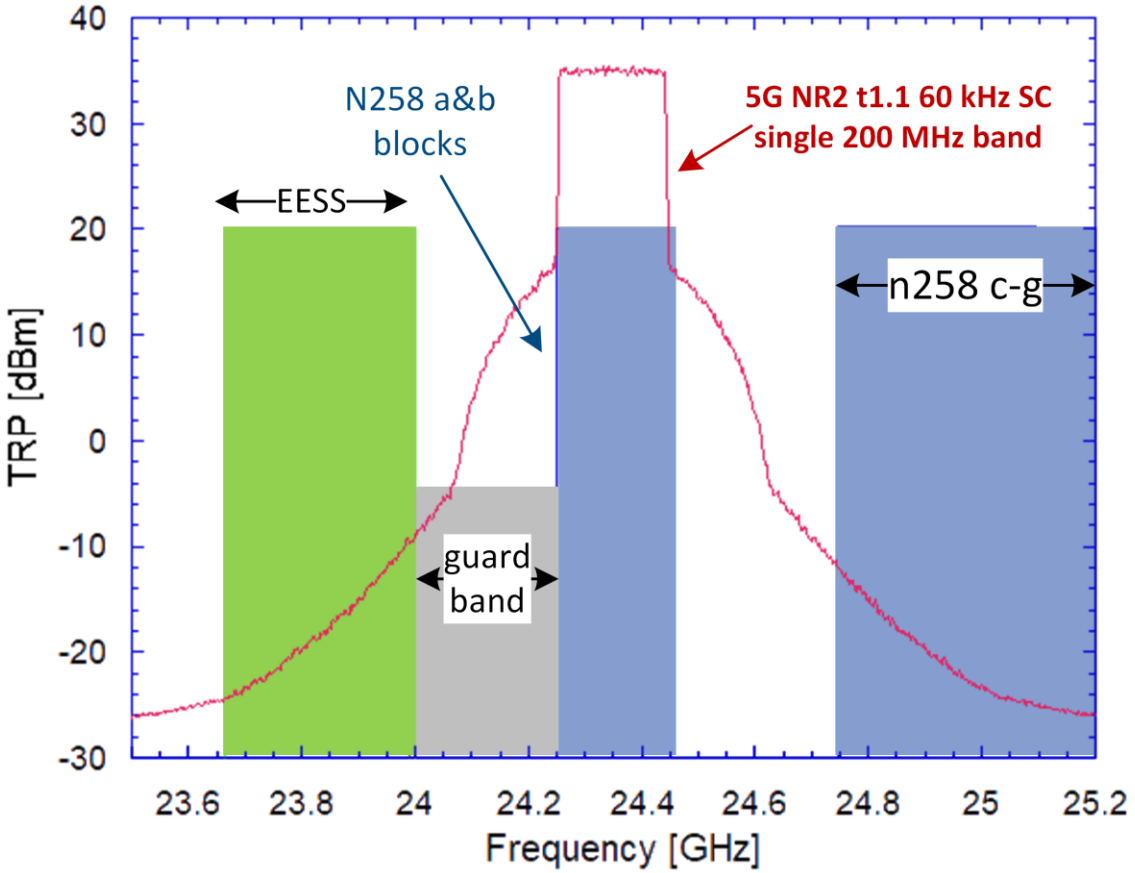
Note: only considering the low power UE amplified to max low power UE in this picture. Should also consider higher power UEs and UE repeater channels.

- Analog MIMO repeaters: network (outside plant), or customer premise equipment (CPE).
- mm-wave 5G issues: coverage, blocking. Many transmission paths NLOS (non line of sight)
- Repeaters improve coverage and blocking issues @1/3 -1/2 cost of a base station.
- Currently deployed @ 28 GHz, forecasts @ 24 GHz ??

5G Repeaters: Issues and Impact

- Are 5G repeaters covered by ITU recommendations (e.g.,WRC-19 agreement on OOB emissions)?
- 5G repeaters will increase base station (gNB) density above ITU => straightforward increase in OOB emissions. Some projections for 1-2 repeaters/cell, particularly in urban/suburban.
- More subtle issues:
  - 5G repeaters may increase (or decrease) OOB emissions beyond increases due to Tx density
    - Amplifiers typically add baseline noise (e.g., amplifier noise figure)
    - RF output filters (and mm-wave plumbing in general) something of an art form. Small changes in component parameters and manufacturing tolerances lead to large changes in filter shapes.
  - How to account for repeaters in the upstream direction?
    - Does 1 repeater double OOB emissions from each UE? (I think so, NR2 is TDM)
    - OSP repeaters may not (probably don't) implement UE Power Control Algorithms => significant potential increase in OOB emissions.
    - Can repeaters transmit at higher TRP/EIRP than UEs? (e.g., class 3 UE with class 1 UE repeater)

Fixed Wireless Access UEs: high power CPE, 3gpp power control



5G NR2 gNB Tx spectrum for nb258 band. gNB's transmit at a fixed power level => gNB OOB emissions levels fixed and independent of Tx power.

- 3gpp power control algorithm (P_{PwrCtl}) increases UE battery life by lowering UE Tx power (in real-time) to maintain an adequate CNR => UE Tx power (& thus OOB emissions) commensurately lower than maximum output power.
- ITU recipe for calculating OOB emissions assumes IMT UEs implement P_{PwrCtl} . The Monte-Carlo simulation adjusts the UE Tx power based on path loss between UE and gNB, thus reducing the OOB emissions.
- ITU 5/1 assumed UE class 3 (e.g., smartphone) Tx levels = 22 dBm. However, new class 1 FWA chipsets (e.g. Qualcom QTM527) provide 35 dBm.
- Do FWA modems turn off P_{PwrCtl} to improve device performance w/o battery penalty? (FWA modems are plugged into line power at the customer premise).

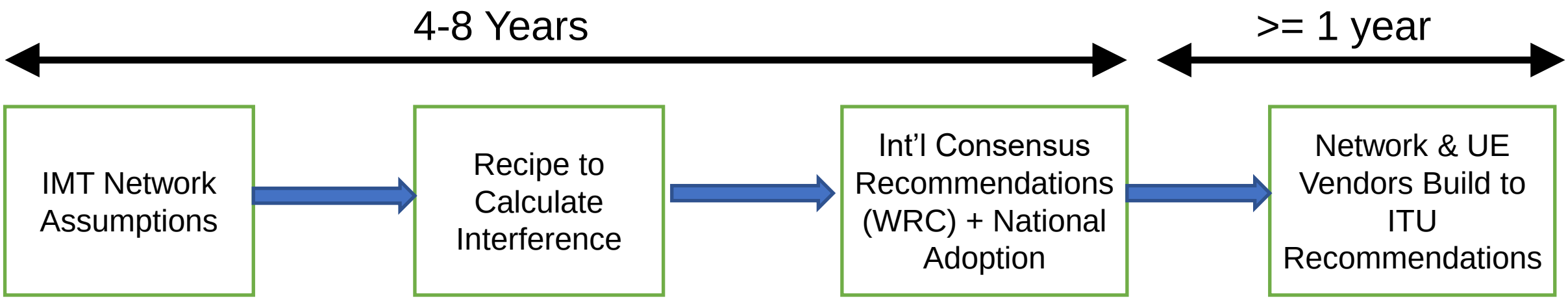
Separate Issue: Qualcom has asked FCC (and other national regulators?) to exempt FWA modems from WRC-19 OOB emission limits. Note that implementing tight OOB emissions on high power customer premise equipment likely harder than for gNBs because the cost of these devices must be constrained

Impact of high power FWA UEs

$$EESS_{Rx} = UE_{Tx} - P_{PwrCtl} - UE_{Gain}\,(\theta_{ue}, \Phi_{ue}) - EESS_{Gain}(\theta_{eess}, \Phi_{eess}) - L_{PathLoss} - L_{other}$$

- Accurate answer requires RF propagation model similar to ITU Recipe (ITU-R M.2101) except:
  - Take into account UE antenna coherence in the OOB spectrum [$UE_{Gain}\,(\theta_{ue}, \Phi_{ue})$]
  - Model both LOS and NLOS using ray tracing and urban topology [$L_{PathLoss}$]. (really only need to do this for a single dense urban EESS pixel to understand impact).
- 2019 “NASA/NOAA Sharing Studies on WRC-10 Agenda Item 1.13” (v2) found that reduction in $EESS_{Rx}$ from P_{PwrCtl} was between 0 and 63 dB.
- If FWA UEs exempt from ITU recommenders (but presumably still bound by 3gpp Adjacent Channel Leakage Ratio requirement of -20 dBm/200 MHz), => 9dB increase in OOB emissions.
- IF FWA UEs do not support 3gpp P_{PwrCtl}, OOBE increase is between 0 and 63 dB. (Run Monte-Carlo simulation w/o P_{PwrCtl}. (for discussion, arbitrarily picked ¼ of 63 dB = 15 dB.)

ITU: processes to mitigate interference from IMT networks



- IMT network assumptions out of date by the time recommendations reach WRC
- Each band must be considered separately, becomes a game of whack a mole
- *Wireless innovation timescale & resources ($$, ££, €€, ¥¥ …) fast and large. Scientific community & regulatory agencies struggle to keep up.*

consider alternatives: real-time geospatial spectrum sharing (RGSS), satellite based interference detection and/or filtering, perhaps others.

Summary:

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- Introduced in late 2019, 5G OSP repeaters and 3GPP class 3 FW Tx are currently deployed in 28 GHz networks, and are expected to be deployed in substantive numbers @ 24 GHz.

- 5G OSP repeaters and class 3 FWA Tx will increase the interference from 5G IMT networks to EESS sounders: 3-5 dB from gNBs & UEs due to repeaters, and 9 – something (24 dB??) from UEs if no P_{PwrCtl}

- Are repeaters covered in WRC-19 recommendations? Do Fixed Wireless Access UE's implement 3GPP power control algorithms? Need to engage regulators and vendors!

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Tx Upstream: WR

TRP/EIRP specs

Class 3)

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