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# 3.5 GHz Band Co-existence Study

December 22, 2014

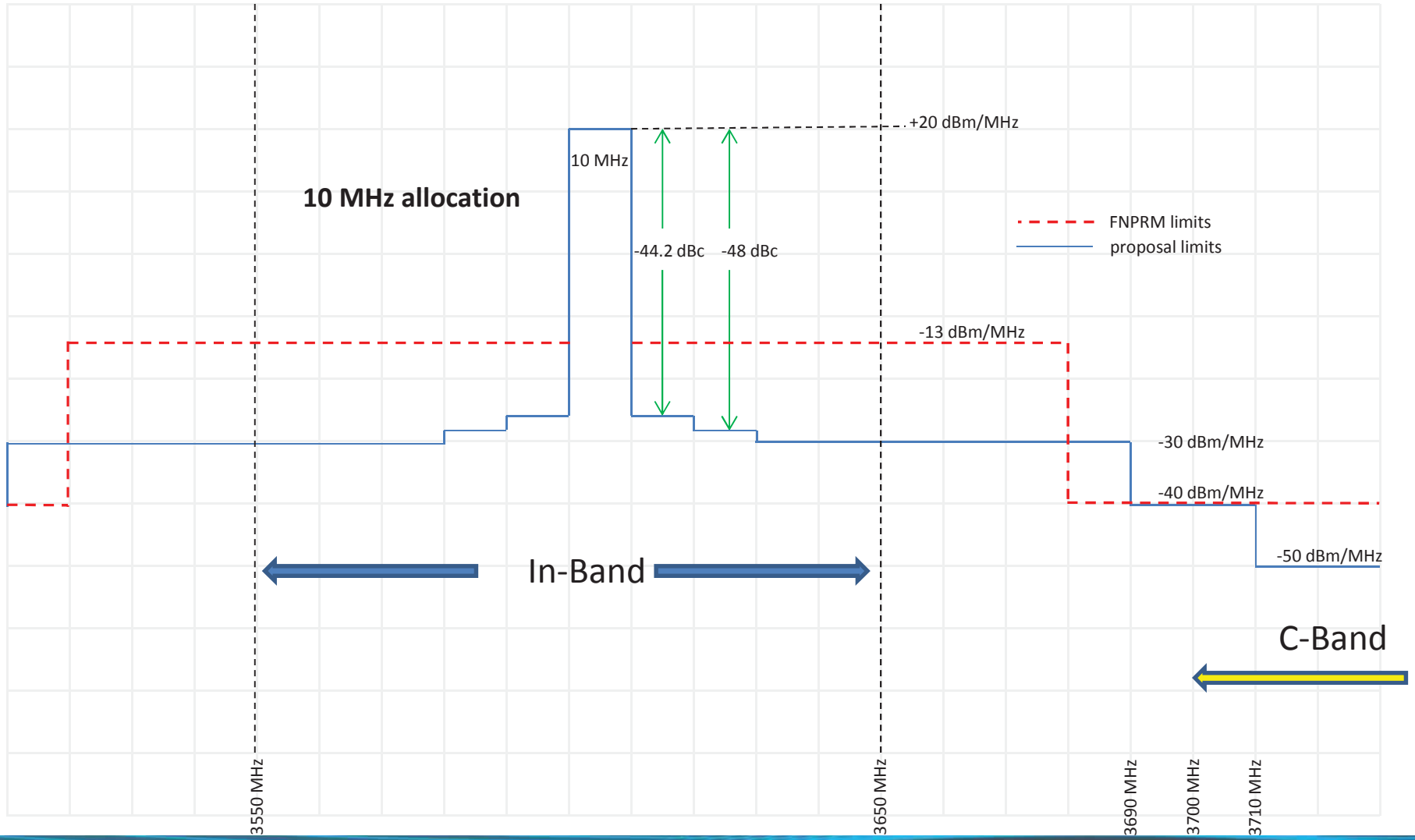
# Topics

- Proposed emissions rules for protecting:
  - Users in 3.5 GHz band
  - C-Band adjacent band services
- Enabling Point-to-Multipoint ("PMP") backhaul services

# Proposed methods for controlling in-band and out-of-band emissions in 3550-3650 MHz band

- TX Power: limit **conducted** Tx Power to +30 dBm/10 MHz power spectral density
  - For 0 dBi antenna, this results in +30 dBm/10MHz EIRP
  - For 17 dBi antenna, this results in +47 dBm/10MHz EIRP
  - As BLiNQ has demonstrated, directionality using higher gain antennas causes less overall network interference compared to omni-directional antennas with similar conducted Tx power. *See* BLiNQ Oct. 31, 2014 *Ex Parte*.
- Adjacent Channel Power: specify Tx Adjacent Channel Leakage Ratio ("ACLR") for 1st and 2nd adjacent channels
  - Bandwidth and air-interface independent (ratio holds for any allocated channel)
  - Allows for 3rd and 5th order controlled roll-off on Tx non-linearities
  - Ensures adjacent channel emissions reduce, at minimum, dB-for-dB for lowered Tx power, reducing network interference
  - Proposal: -44.2 decibels relative to carrier ("dBc") for the adjacent carrier; -48 dBc for the alternate adjacent carrier.
    - Consistent with global 3GPP standards and existing device technologies, including test tolerance ref. ETSI TS 136 141 v11.4.0 LTE BS Performance Testing; and ETSI EN 302 774 v1.2.0 BWA in 3400-3800 MHz frequency bands.
- Limit ***in-band*** (3550-3650 MHz) emissions at > 2.5x channel bandwidth offset to -30 dBm/MHz (60+10*logP) vs currently proposed -13 dBm/MHz
- Limit ***out-of-band*** (C-Band 3700-4200 MHz) emissions to
  - -40dBm/MHz for >40 MHz offset from 3.5 band edge (70+10*logP)
  - -50dBm/MHz for >60MHz offset from 3.5 band edge (80+10*logP)

# Conducted TX Power & Emissions



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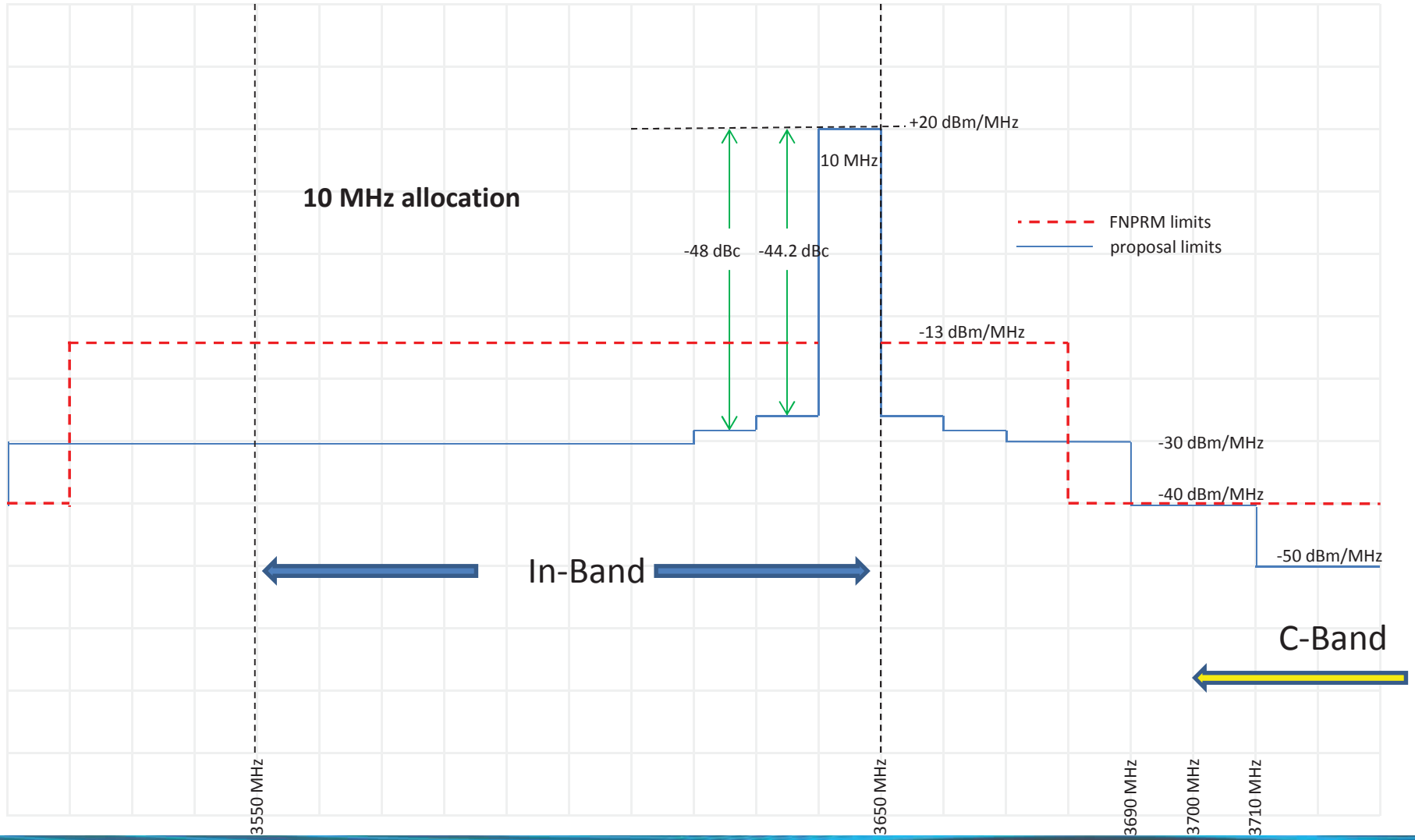

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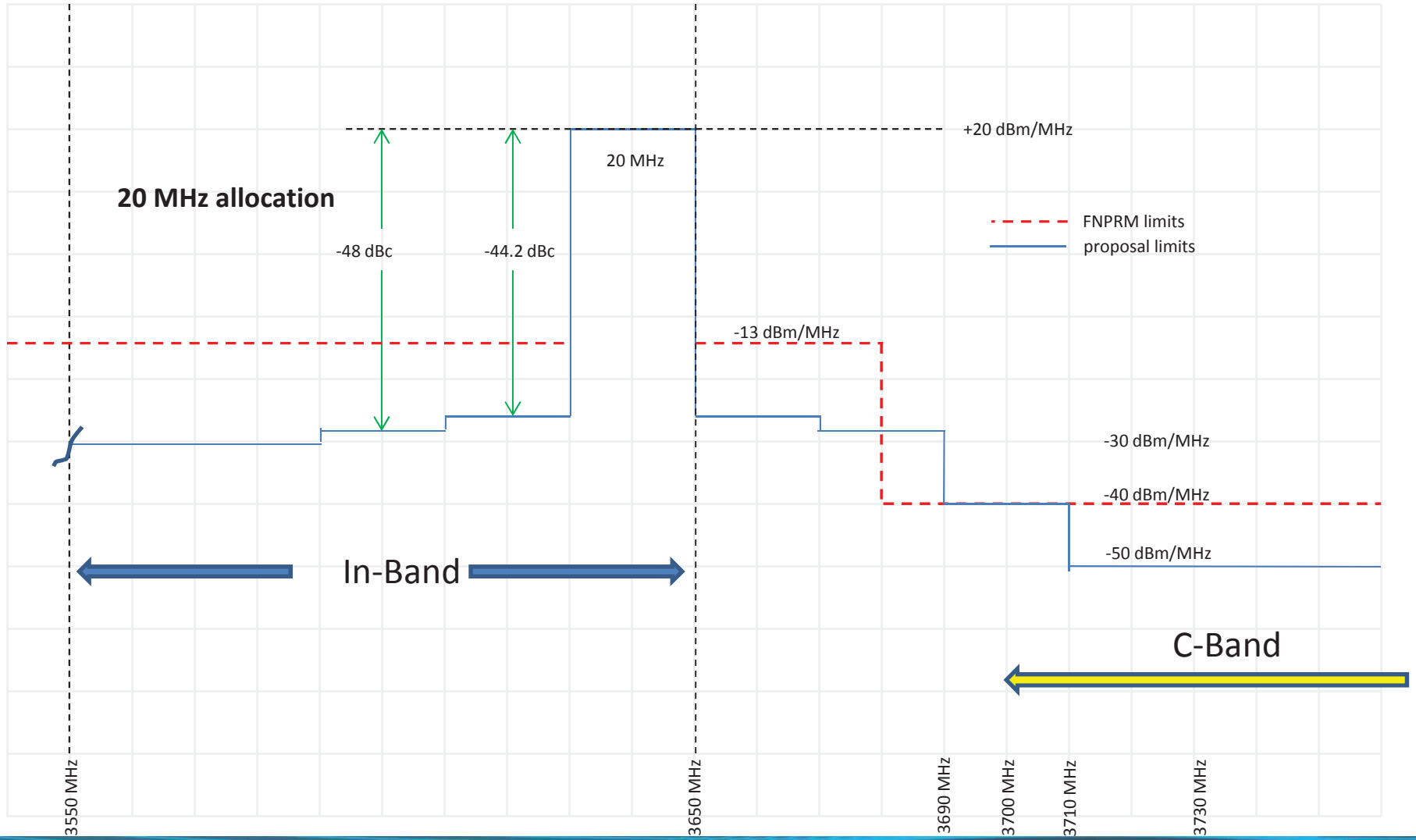

# Protection of Users in 3.5 GHz band

## Adjacent Channel Leakage Ratio & Proposed Limits

- Effective method of controlling transmitter in-band emissions and protecting other users in the band.
- Adjacent Channel Leakage Ratio is defined as the ratio of the transmitted power to the power in the adjacent radio channel, both measured after the receive filter. The measurement integrated bandwidth used is typically one which contains 99.9% of the transmit energy (channel bandwidth ("Ch. BW")). The adjacent channel center frequency is +/- 1x Ch. BW offset from transmit carrier frequency.
- Expected use of the 3.5 GHz band is RF carriers having uniform power density over a given bandwidth (10 MHz is smallest allocation currently envisioned), such as LTE 4G RF signaling. No expected use case of "narrow-band" RF carriers i.e. <1 MHz; thus, the most meaningful in-band interference metric is interfering level power integrated over an assigned RF channel bandwidth.
- Example:
  - For a +30 dBm/10 MHz transmitter, assigned to 10 MHz of spectrum allocation, ACLR of 44.2 dBc results in -14.2 dBm/10 MHz of absolute conducted emissions level.
  - To put into context, assuming flat transmitter emissions in the adjacent channel, the resulting levels are -24.2 dBm/MHz. This may be compared to previous in-band relative attenuation levels of 43+10*logP, which result in -13 dBm/MHz absolute conducted emissions levels.
- Alternate Adjacent Channel Leakage Ratio proposed in a similar way, with a limit of 48 dBc. The alternate adjacent channel center frequency is +/- 2x Ch. BW offset from transmit carrier frequency.
- Require transmitters to hold ACLR performance over full Tx dynamic range, ensures lower network interference for all Tx power levels.

# C-Band Earth Station Protection

## for fixed 3.5 GHz band installations

- There is large variation in protection distance requirements for C-Band earth stations due to 3.5 GHz band emissions vs frequency offset and possible propagation path profiles between transmitter and receiver.
- In order to support higher spectrum utilization while simultaneously protecting C-Band earth stations, BLiNQ suggests the following approach:
  - Specify practical 3.5 GHz band out-of-band emissions requirements. Consistent with all possible spectrum uses.
    - Power density rules, maximum channel allocation, typical transmitter non-linearities, etc.
  - Employ SAS database with protection distance calculator for deployments near C-Band earth stations
    - Calculator takes into account 3.5 GHz radio parameters, antenna pointing, terrain/topology between proposed radio and C-Band earth station
    - Go/No-go determination based on predetermined set of rules used by calculator

# Example showing need for SAS & Protection Distance Calculator – Effect of 3.5 GHz Band OOBE

- C-Band Earth Station parameters

| C-Band interference threshold | | |
|---|---|---|
| temp(K) | 143.00 | degK |
| kTB | -177.05 | dBm/Hz |
| kTB | -117.05 | dBm/MHz |
| I/N | -10.00 | dB |
| inter. objective | -127.05 | dBm/MHz |

| ES antenna off-axis angle | Gain toward 3.5 GHz transmitter | |
|---|---|---|
| 5 | 14.5 | dB |
| 15 | 2.6 | |
| 30 | -4.9 | |
| 48 | -10 | |

- Simulation setup
  - 3.5 GHz transmitter, OOBE of -30 dBm/MHz and -40 dBm/MHz representing practical emissions at various offsets from channel edge
  - Antenna Cases
    - Case 1: Earth Station ("ES") antenna off-axis angle 5 degrees from horizon 14.5 dBi at this angle toward CBSD transmitter 14 dBi pointed directly at ES antenna
    - Case 2: ES antenna off-axis angle 15 degrees from horizon 2.6 dBi at this angle toward CBSD transmitter 14 dBi pointed directly at ES antenna
  - Propagation path models
    - Free-space model with path loss exponent at R^2 (line-of-sight ("LOS")) and R^2.8 (non-line-of-sight ("nLOS"))

| | protection distance | |
|---|---|---|
| R^2, -30 dBm/MHz, antenna case 1 | 11600 | m |
| R^2, -40 dBm/MHz, antenna case 1 | 3600 | m |
| R^2.8, -30 dBm/MHz, antenna case 1 | 1540 | m |
| R^2.8, -40 dBm/MHz, antenna case 1 | 680 | m |
| R^2, -30 dBm/MHz, antenna case 2 | 3100 | m |
| R^2, -40 dBm/MHz, antenna case 2 | 980 | m |
| R^2.8, -30 dBm/MHz, antenna case 2 | 600 | m |
| R^2.8, -40 dBm/MHz, antenna case 2 | 260 | m |

- Conclusion
  - Large variations in computed protection distances; yields poor spectrum utilization for worst-case assumptions
  - SAS coordinator with protection distance calculator can create a more flexible and efficient use of spectrum allowing co-existence between new 3.5 GHz band installations and existing C-Band earth stations.



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# Example showing need for SAS & Protection Distance Calculator – Effect of C-Band LNB saturation

- C-Band Earth Station parameters
  - Low Noise Block downconverter ("LNB") saturation target of -55 dBm
  - LNB front end filter 5, 10 dB attenuation of 3.5 GHz band transmitter, representing various offsets from band edge

| ES antenna off-axis angle | Gain toward 3.5 GHz transmitter | |
|---|---|---|
| 5 | 14.5 | dB |
| 15 | 2.6 | |
| 30 | -4.9 | |
| 48 | -10 | |

- Simulation setup
  - 3.5 GHz transmitter +30 dBm/10 MHz conducted TX power
  - Antenna Cases
    - Case 1: ES antenna off-axis angle 5 degrees from horizon 14.5 dBi at this angle toward CBSD transmitter 14 dBi pointed directly at ES antenna
    - Case 2: ES antenna off-axis angle 15 degrees from horizon 2.6 dBi at this angle toward CBSD transmitter 14 dBi pointed directly at ES antenna
  - Propagation path models
    - Free-space model with path loss exponent at R^2 (LOS) and R^2.8 (nLOS)

| | clear distance | |
|---|---|---|
| R^2, 5 dB filter, antenna case 1 | 1620 | m |
| R^2, 10 dB filter, antenna case 1 | 920 | m |
| R^2.8, 5 dB filter, antenna case 1 | 380 | m |
| R^2.8, 10 dB filter, antenna case 1 | 250 | m |
| R^2, 5 dB filter, antenna case 2 | 440 | m |
| R^2, 10 dB filter, antenna case 2 | 250 | m |
| R^2.8, 5 dB filter, antenna case 2 | 150 | m |
| R^2.8, 10 dB filter, antenna case 2 | 100 | m |

- Conclusion
  - Not as critical compared to 3.5 GHz band OOBE, but large variations as well due to various assumptions
  - SAS coordinator with protection distance calculator can create a more flexible and efficient use of spectrum allowing co-existence between new 3.5 GHz band installations and existing C-Band earth stations.



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# C-band Earth Station Analysis Conclusions

- Co-existence of proposed 3.5 GHz Band radios with existing C-Band earth stations:
  - 3.5 GHz band OOBE effect on C-Band receiver performance (co-channel interference)
  - 3.5 GHz band transmitter causing C-Band LNB saturation due to close proximity
- Analysis indicates that 3.5 GHz Band OOBE is more sensitive parameter for co-existence compared to 3.5 GHz Band transmitter-caused receiver saturation.
- Large variation in clearance distances based on assumptions – RF path profile, emissions, and antenna pointing angles.
- Intelligent SAS utilizing active protection zone calculator can improve spectrum utilization and band usage, while at the same time protecting adjacent band incumbents. SAS requires basic radio parameters (transmit power, antenna properties, location, pointing) to become effective utilization tool prior to granting of access.

# Enabling Point-to-Multipoint (PMP)

- The Commission can establish PMP rules that enable such technologies for Small Cell backhaul in the 3.5 GHz band, while at the same time, limiting the amount of network-level interference.
- Previous simulations indicate a highly directional antenna system produces far less network-level interference than lower EIRP omni-directional antenna systems for the same conducted TX power.
- To further limit interference, PMP systems utilized for backhaul may be restricted to maximum number of subtending remote fixed terminals.
  - Potential limit: 6 subtending remote fixed terminals.
  - This numerical limitation will avoid high power access-like systems, with excessively high number of Remotes in a given sector.
- To avoid "high-powered omni" deployments, rules may be established that limit applications of co-located high-power PMP systems:
  - Limit azimuthal coverage per co-located transmitter site– e.g. less than 120 degrees
    - Configurations exceeding this azimuthal coverage must transmit on different frequencies
    - Co-located radios may operate on the same channel so long as cumulative azimuthal coverage does not exceed 120 degrees

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# Thank You!

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