



5G NR Physical Layer/Waveforms

Laboratory Division
Office of Engineering and Technology
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Introduction

- 5G NR Implements changes to physical layer structure via a phased approach:
 - Wave 1:
 - Optimizes currently used physical layer based on 4G LTE
 - Multiple Access: CP-OFDM and DFT-s-OFDM
 - Physical Channels and Modulation
 - Wave 2:
 - Studies new waveforms, non-orthogonal multiple access (NOMA)
 - Explores new spectrum beyond 52.6 GHz



Frame Structure

● Numerologies

- Unlike 4G LTE, 5G NR supports multiple sub carrier spacing (SCS)
- SCS: $15 \text{ kHz multiplied by } (2^\mu)$ where $\mu = 0,1,2,3,4$
- Depending on bandwidth and frequency of transmitted signal, SCS can be 15, 30, 60, 120 or 240 kHz
 - Given the subframe length is fixed (1 ms), number of slots per subframe increases as μ increases
- Additionally, 5G NR uses mini-slots (with 2, 4 or 7 symbols) for low latency applications



Compliance Testing Considerations

- While 3GPP may define physical layer characteristics in a bandwidth (and band) agnostic way, FCC Regulatory compliance testing is band and rule specific.
- Compliance testing should consider all possible configurations including the following based on the appropriate rules:
 - Maximum Output Power
 - Transmission Bandwidth
 - Carrier(s) Frequency
 - Carrier Aggregation, etc.
 - Numerology
 - Multiple Subcarrier Spacings
 - Modulation
 - Beamforming Capability, ...



Compliance Verification/ Measurement Methods for Part 30 Devices

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Summary of Technical Rules

● Part 30

– Transmit Power

- The average power of the sum of all antenna elements is limited to a maximum EIRP or EIRP Density of
 - +75 dBm/100 MHz (Fixed and Base Stations)
 - +43 dBm (Mobile Stations)
 - +55 dBm (Transportable Stations)
- For fixed P2P or PMP, the maximum allowable EIRP is as specified in §30.405

– Out of Band Emission (OOBE)

- The conductive power or the **total radiated power** of any emission outside a licensee's frequency block
 - – 5 dBm/MHz (in the bands immediately outside and adjacent to the licensee's frequency block, having a bandwidth equal to 10 percent of the channel bandwidth)
 - –13 dBm/MHz or lower (elsewhere)
- For fixed P2P or PMP, the mean power of emissions must meet the limits in accordance with the schedule in §30.404(a)



TRP Compliance Procedure

- Total Radiated Power (TRP)
 - New RF parameter for compliance verification
 - Introduced in FCC R/O, FCC16-89
 - Main focus of C63 mmW JTG test procedure developmental efforts
- Multiple methods to measure TRP developed by C63 mmW JTG
 - Two (or three) Cut Method
 - Equal Sector Method
 - Spherical Method



Compliance Verification Procedures

- The FCC published guidance applicable to Part 30 devices
 - Draft guidance was published for commenting on February 1, 2019
 - Final guidance was published on April 5, 2019
 - KDB Publication 842590 D01
- The FCC final publication addresses:
 - TRP: adopting TRP measurement procedure developed by ANSI C63 mmW JTG for OOB and spurious emission
 - RF Power, OBW, etc.:
 - Compliance verification measurements IAW ANSI-C63.26-2015
 - alternative method to verify OOB compliance at the band-edge
- The Lab will also consider and review alternative Compliance verification methods



Test Configurations and Criteria

- Test Configurations for:
 - (in-band)RF Power Measurement
 - OOB Emission Measurements
 - Spurious Emission Measurements
- Test Channels (Frequencies)
 - 3GPP- Compliant Devices
 - Non 3GPP-compliant Devices
- Measurement Distance
- Beam Identification



Power Measurements-1

- In-band RF Power
 - Requirement: EIRP
 - Verification: EIRP Measurement
 - Setup for radiated (EIRP) Measurement
 - Max EIRP is subject to the limit
 - Compliance measurement may be performed with*
 - multiple beams at rated maximum EIRP
 - Beams can carry equal or unequal power
 - Single beam at rated maximum EIRP

*Typically the single beam with highest gain defines the max EIRP.



Power Measurements-2

● OOB Emission

- Requirement: TRP/Conducted Power
- Verification: EIRP, TRP, Conducted Power Measurements (or EIRP to Conducted Power Conversion)
- If the measured EIRP meets the TRP limit the device meets the requirement on that frequency
- Otherwise, perform TRP measurements as described in KDB Publication 842590 D01
- EIRP to conducted power conversion
 - Only allowed for band edge
 - Only when realized gain of EUT available in given polarity as a function of frequency over the OOBE measurement range (both edges of the band)



Power Measurements-3

- Spurious Emission
 - Requirement: TRP/Conducted Power
 - Verification: EIRP, TRP or Conducted Power Measurement
 - If the measured EIRP meets the TRP limit the device meets the requirement on that frequency
 - Otherwise, perform TRP measurements as described in KDB Publication 842590 D01
 - EIRP to Conducted Power Conversion **NOT Allowed**



Power Measurements-4

- OOB and Spurious Emissions (Unwanted Emissions)
 - Determining worst case can be challenging
 - Can be determined by the OEM or manufacturer
 - The EUT shall be evaluated for at least one of the beam configurations below:
 - EUT configured to transmit a single beam at a rated maximum EIRP
 - EUT is configured to transmit at rated maximum EIRP with several beams with equal power levels
 - EUT is configured to transmit at rated maximum EIRP with several beams with equal power levels



Test (Measurement) Distance

- For the purpose of compliance testing of Part 30 devices, The far field boundary is defined as $2 \frac{D^2}{\lambda}$

Where

D is the largest dimension of the antenna.
For aperture antennas, D is considered to be the diagonal of the aperture.

λ is the wavelength of the transmission



Test Frequencies

- The basic principle of testing at least three frequencies (low, medium, high) still holds
- For OOB compliance measurement, Overall guidance is to tune the transmission as close to the band edge as practically possible
- 3GPP-compliant devices may select test frequencies as described in 3GPP 38-508-1 specification



Vehicular Radar Certification Under Part 95 Subpart M: Updates to Equipment Authorization Guidance Provided in KDB 653005

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Transition Deadlines

Part 15.37 (l) through (n)

- New applications for certification of vehicular radar devices under Parts 15.252 and 15.515 no longer being accepted.
 - Grandfather provision expired in September, 2018
- Class II permissive changes still permitted until 1 January 2022.
- Manufacture, importation, marketing, sale, and installation will no longer be permitted after 1 January 2022, with limited exceptions
 - Continued sales and installation permitted for the purpose of repairing or replacing defective, damaged, or potentially malfunctioning equipment that was installed prior to 1 January 2022.



Clarification of Technical Requirements

- Radiated Power Limits
 - Clarified that the peak power limit (55 dBm) is expressed as a power spectral density (i.e., peak power measured within any 1 MHz).
 - Resolves challenges of measuring peak power over very wide bandwidth.
 - Ensures harmony with ISED interpretation.
- Occupied Bandwidth
 - Shall be measured with the sweep active (FMCW)
 - Must ensure that OBW remains within the authorized frequency band under extreme temperature and voltage conditions (2.1055)
- Unwanted Emissions
 - Shall be investigated up to 231 GHz (95.3379), but should be investigated up to 243 GHz (maximum third harmonic frequency).