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**LTE;**  
**Evolved Universal Terrestrial Radio Access (E-UTRA);**  
**Physical channels and modulation**  
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# Foreword

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# 1 Scope

The present document describes the physical channels for evolved UTRA.

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# 2 References

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- [2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description".
- [3] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".
- [4] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".
- [5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".
- [6] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".
- [7] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".
- [8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".
- [9] 3GPP TS 36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol specification"
- [10] 3GPP TS 36.304, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode"
- [11] 3GPP TS 37.213: "Physical layer procedures for shared spectrum channel access"
- [12] 3GPP TS 36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2"

## 3 Symbols and abbreviations

### 3.1 Symbols

For the purposes of the present document, the following symbols apply:

$(k, l)$	Resource element with frequency-domain index $k$ and time-domain index $l$
$a_{k,l}^{(p)}$	Value of resource element $(k, l)$ [for antenna port $p$ ]
$D$	Matrix for supporting cyclic delay diversity
$D_{RA}$	Density of random access opportunities per radio frame
$f_0$	Carrier frequency
$f_{RA}$	PRACH resource frequency index within the considered time-domain location
$f_{PRB,hop}^{PRACH}$	PRACH frequency hopping offset, expressed as a number of resource blocks
$l_{NPDCCHStar}$	Start symbol in slot 0 for NPDCCH
$l_{NPDSCHStar}$	Start symbol in slot 0 for NPDSCH
$M_{sc}^{PSBCH}$	Bandwidth for PSBCH transmission, expressed as a number of subcarriers
$M_{RB}^{PSBCH}$	Bandwidth for PSBCH transmission, expressed as a number of resource blocks
$M_{sc}^{PSCCH}$	Bandwidth for PSCCH transmission, expressed as a number of subcarriers
$M_{RB}^{PSCCH}$	Bandwidth for PSCCH transmission, expressed as a number of resource blocks
$M_{sc}^{PSDCH}$	Bandwidth for PSDCH transmission, expressed as a number of subcarriers
$M_{RB}^{PSDCH}$	Bandwidth for PSDCH transmission, expressed as a number of resource blocks
$M_{sc}^{PSSCH}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of subcarriers
$M_{RB}^{PSSCH}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of resource blocks
$M_{sc}^{PUSCH}$	Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers
$M_{RB}^{PUSCH}$	Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks
$M_{rep}^{NPUSCH}$	Scheduled number of repetitions of a NPUSCH transmission
$M_{rep}^{NPDSCH}$	Scheduled number of repetitions of a NPDSCH transmission
$M_{sc}^{NPUSCH}$	Scheduled bandwidth for uplink NPUSCH transmission, expressed as a number of subcarriers
$M_{identical}^{NPUSCH}$	Number of repetitions of identical slots for NPUSCH
$M_{bit}^{(q)}$	Number of coded bits to transmit on a physical channel [for codeword $q$ ]
$M_{symb}^{(q)}$	Number of modulation symbols to transmit on a physical channel [for codeword $q$ ]
$M_{symb}^{layer}$	Number of modulation symbols to transmit per layer for a physical channel
$M_{symb}^{ap}$	Number of modulation symbols to transmit per antenna port for a physical channel
$M_{sc}^{RU}$	Number of consecutive subcarriers in an UL resource unit for PUSCH sub-PRB allocation
$M_{slots}^{UL}$	Number of slots in an UL resource unit for PUSCH sub-PRB allocation
$M_{symb}^{UL}$	Number of SC-FDMA symbols in an uplink slot for PUSCH sub-PRB allocation
$M_{Seq}^{RU}$	Number of reference signal sequences available for the UL resource unit size for PUSCH sub-PRB allocation
$M_{RU}$	Number of scheduled UL resource units for PUSCH sub-PRB allocation
$N$	A constant equal to 2048 for $\Delta f = 15$ kHz, 4096 for $\Delta f = 7.5$ kHz and 8192 for $\Delta f = 3.75$ kHz
$N_{CP,l}$	Downlink cyclic prefix length for OFDM symbol $l$ in a slot

$N_{CS}$	Cyclic shift value used for random access preamble generation
$N_{cs}^{(1)}$	Number of cyclic shifts used for PUCCH formats 1/1a/1b in a resource block with a mix of formats 1/1a/1b and 2/2a/2b
$N_{RB}^{(2)}$	Bandwidth available for use by PUCCH formats 2/2a/2b, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{HO}$	The offset used for PUSCH frequency hopping, expressed in number of resource blocks (set by higher layers)
$N_{ID}^{cell}$	Physical layer cell identity
$N_{ID}^{Ncell}$	Narrowband physical layer cell identity
$N_{ID}^{MBSFN}$	MBSFN area identity
$N_{ID}^{SL}$	Physical layer sidelink synchronization identity
$N_{ID}^{PRS}$	Positioning reference signal identity
$N_{RB}^{DL}$	Downlink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{min,DL}$	Smallest downlink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{max,DL}$	Largest downlink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{UL}$	Uplink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{min,UL}$	Smallest uplink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{max,UL}$	Largest uplink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RB}^{SL}$	Sidelink bandwidth configuration, expressed in multiples of $N_{sc}^{RB}$
$N_{RSS}$	Duration of RSS measured in subframes
$N_{SF}$	Number of scheduled subframes for NPDSCH transmission
$N_{symb}^{NPSS}$	Number of symbols for NPSS in a subframe
$N_{symb}^{NSSS}$	Number of symbols for NSSS in a subframe
$N_{sc}^{RU}$	Number of consecutive subcarriers in an UL resource unit for NB-IoT
$N_{seq}^{RU}$	Number of reference signal sequences available for the UL resource unit size
$N_{RU}$	Number of scheduled UL resource units for NB-IoT
$N_{NB}^{UL}$	Total number of uplink narrowbands
$N_{WB}^{UL}$	Total number of uplink widebands
$N_{sc}^{UL}$	Number of subcarriers in the frequency domain for NB-IoT
$N_{acc}$	Number of consecutive absolute subframes over which the scrambling sequence stays the same
$N_{abs}^{PUSCH}$	Total number of absolute subframes a PUSCH with repetition spans expressed as a number of absolute subframes
$N_{rep}^{PUSCH}$	Number of repetitions of a PUSCH transmission
$N_{NB}^{ch,UL}$	Number of consecutive absolute subframes over which PUCCH or PUSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$f_{NB,hop}^{PUSCH}$	Narrowband offset between one narrowband and the next narrowband a PUSCH hops to, expressed as a number of uplink narrowbands
$N_{abs}^{PUCCH}$	Total number of absolute subframes a PUCCH with repetition spans, expressed as a number of absolute subframes
$N_{rep}^{PUCCH}$	Number of repetitions of a PUCCH transmission
$N_{rep}^{PRACH}$	Number of PRACH repetitions per preamble transmission attempt
$N_{sf}^{RA}$	Number of subframes allowed for preamble transmission within a 1024-frame interval

$N_{\text{start}}^{\text{PRACH}}$	PRACH starting subframe periodicity
$N_{\text{rep}}^{\text{NPRACH}}$	Number of NPRACH repetitions per preamble transmission attempt
$N_{\text{period}}^{\text{NPRACH}}$	NPRACH resource periodicity
$N_{\text{scoffset}}^{\text{NPRACH}}$	Frequency location of the first sub-carrier allocated to NPRACH
$N_{\text{sc}}^{\text{NPRACH}}$	Number of sub-carriers allocated to NPRACH
$N_{\text{sc\_cont}}^{\text{NPRACH}}$	Number of starting sub-carriers allocated for UE initiated random access
$N_{\text{start}}^{\text{NPRACH}}$	NPRACH starting subframe
$N_{\text{MSG3}}^{\text{NPRACH}}$	Fraction for starting subcarrier index for UE support for multi-tone msg3 transmission
$N_{\text{gapperiod}}$	Periodicity for NPDSCH/NPDCCH gaps
$N_{\text{gapduration}}$	Duration for NPDSCH/NPDCCH gaps
$N_{\text{gapthreshold}}$	Threshold for applying NPDCCH/NPDCCH gaps
$N_{\text{NB}}^{\text{DL}}$	Total number of downlink narrowbands
$N_{\text{WB}}^{\text{DL}}$	Total number of downlink widebands
$N_{\text{abs}}^{\text{PDSCH}}$	Total number of absolute subframes a PDSCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{PDSCH}}$	Number of repetitions of a PDSCH transmission
$N_{\text{NB}}^{\text{ch,DL}}$	Number of consecutive absolute subframes over which MPDCCH or PDSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$N_{\text{NB,hop}}^{\text{ch,DL}}$	Number of narrowbands over which MPDCCH or PDSCH frequency hops
$f_{\text{NB,hop}}^{\text{DL}}$	Narrowband offset between one narrowband and the next narrowband an MPDCCH or PDSCH hops to, expressed as a number of downlink narrowbands
$N_{\text{PDSCH}}^{\text{SIB1-BR}}$	Number of times a PDSCH carrying SIB1-BR is transmitted over 8 radio frames
$N_{\text{abs}}^{\text{MPDCCH}}$	Total number of absolute subframes a MPDCCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{MPDCCH}}$	Number of repetitions of a MPDCCH transmission
$N_{\text{abs,ss}}^{\text{MPDCCH}}$	Total number of absolute subframes a MPDCCH search space with maximum repetition level spans, expressed as a number of absolute subframes
$N_{\text{rep,ss}}^{\text{MPDCCH}}$	Maximum repetition level of a MPDCCH search space
$N_{\text{ECCE}}^{\text{MPDCCH}}$	Number of ECCEs in a subframe for one MPDCCH
$N_{\text{symb}}^{\text{DL}}$	Number of OFDM symbols in a downlink slot
$N_{\text{symb}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\text{symb}}^{\text{retune}}$	Number of symbols in a guard period for narrowband or wideband retuning
$N_{\text{slots}}^{\text{UL}}$	Number of consecutive slots in an UL resource unit for NB-IoT
$N_{\text{symb}}^{\text{SL}}$	Number of SC-FDMA symbols in a sidelink slot
$N_{\text{sc}}^{\text{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
$N_{\text{sb}}$	Number of sub-bands for PUSCH frequency-hopping with predefined hopping pattern
$N_{\text{RB}}^{\text{sb}}$	Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks
$N_{\text{sc}}^{\text{RA}}$	Size of narrow-band random-access resource in number of subcarriers
$N_{\text{SP}}$	Number of downlink to uplink switch points within the radio frame
$N_{\text{RS}}^{\text{PUCCH}}$	Number of reference symbols per slot for PUCCH

$N_{RS}^{SPUCCH}$	Number of reference symbols per subslot or per slot for SPUCCH
$N_{TA}$	Timing offset between uplink and downlink radio frames at the UE, expressed in units of $T_s$
$N_{TA\text{ offset}}$	Fixed timing advance offset, expressed in units of $T_s$
$N_{TA,SL}$	Timing offset between sidelink and timing reference frames at the UE, expressed in units of $T_s$
$n_{PUCCH}^{(1,\tilde{p})}$	Resource index for PUCCH formats 1/1a/1b
$n_{PUCCH}^{(2,\tilde{p})}$	Resource index for PUCCH formats 2/2a/2b
$n_{PUCCH}^{(3,\tilde{p})}$	Resource index for PUCCH format 3
$n_{PDCCH}$	Number of PDCCHs present in a subframe
$n_{PRB}$	Physical resource block number
$n_{PRB}^{RA}$	First physical resource block occupied by PRACH resource considered
$n_{PRB\text{ offset}}^{RA}$	First physical resource block available for PRACH
$n_{PRB,RSS}$	Lowest PRB number of RSS
$n_{sc}^{RA}$	Subcarrier occupied by NPRACH resource considered
$n_{VRB}$	Virtual resource block number
$n_{RNTI}$	Radio network temporary identifier
$n_{ID}^{SA}$	Sidelink group destination identity
$n_f$	System frame number
$n_s$	Slot number within a radio frame
$n_{sf}^{abs}$	Absolute subframe number
$n_{sf}^{RA}$	Index for subframes allowed for preamble transmission
$O_{RSS}$	Starting frame offset of RSS in each RSS period
$P$	Number of antenna ports used for transmission of a channel
$p$	Antenna port number
$P_{RSS}$	Period of RSS measured in frames
$q$	Codeword number
$r_{RA}$	Index for PRACH versions with same preamble format and PRACH density
$Q_m$	Modulation order: 1 for $\pi/2$ -BPSK, 2 for QPSK, 4 for 16QAM, 6 for 64QAM and 8 for 256QAM transmissions
$s_l^{(p)}(t)$	Time-continuous baseband signal for antenna port $p$ and OFDM symbol $l$ in a slot
$t_{RA}^{(0)}$	Radio frame indicator index of PRACH opportunity
$t_{RA}^{(1)}$	Half frame index of PRACH opportunity within the radio frame
$t_{RA}^{(2)}$	Uplink subframe number for start of PRACH opportunity within the half frame
$T_f$	Radio frame duration
$T_s$	Basic time unit
$T_{slot}$	Slot duration
$W$	Precoding matrix for downlink spatial multiplexing
$\beta_{PRACH}$	Amplitude scaling for PRACH
$\beta_{NPRACH}$	Amplitude scaling for NPRACH
$\beta_{PUCCH}$	Amplitude scaling for PUCCH
$\beta_{PUSCH}$	Amplitude scaling for PUSCH
$\beta_{NPUSCH}$	Amplitude scaling for NPUSCH
$\beta_{SPUCCH}$	Amplitude scaling for SPUCCH
$\beta_{SRS}$	Amplitude scaling for sounding reference symbols
$\Delta f$	Subcarrier spacing