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Maximum Transmit Power Level Controller Architecture for Simultaneous Transmission

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MAXIMUM TRANSMIT POWER LEVEL CONTROLLER ARCHITECTURE FOR SIMULTANEOUS TRANSMISSION

Abstract

A mobile device configured to operate within a wireless communication network includes a Maximum Transmit Power Level (MTPL) controller. In order to meet specific absorption rate (SAR) limit requirements during simultaneous transmissions or during a dual connection mode, the mobile device employs a compact look-up table containing MTPL values and offset values. The MTPL controller generates runtime MTPL values for instances when the mobile device is operating in a stand-alone mode and for instances when the mobile device is operating in a simultaneous transmission mode. In the simultaneous transmission mode, the runtime MTPL value is generated by offsetting an MTPL value by an offset value.

Background

Specific absorption rate (SAR) is an indication of the amount of radiation absorbed by a user when exposed to a radio frequency (RF) electromagnetic field, such as those generated by mobile telephones and other mobile devices. The SAR value of a particular device is significantly dependent on the geometry of the body part exposed to the RF energy, and also on the location, geometry, and transmission power of the RF source. Due to the potential for harm to human tissues caused by exposure to RF electromagnetic fields, some governments have adopted SAR limits for devices intended to operate in close proximity to the body. Thus, mobile devices sold in these countries must comply with the set SAR limits for safe exposure.

Meeting SAR requirements for a mobile device can be addressed by adjusting the upper limit of power at which the antenna of the device operates. This upper limit of transmit power may be constrained by a Maximum Transmit Power Level (MTPL), which is generally available to a device in an MTPL look-up table. In mobile devices configured to simultaneously transmit via multiple transmitters (e.g., cellular and connectivity transmitters), the MTPL look-up table can become relatively large as it typically includes entries for both stand-alone mode (i.e., only one transmitter operating at a given time) and simultaneous transmission mode (i.e., multiple transmitters operating at the same time). In some systems, feature and chipset planning limitations preclude the use of such large MTPL look-up tables.

Description

A conventional wireless communication network generally includes a base station and at least one mobile device. The mobile devices of the communication network include at least one antenna, a connectivity transmitter, a cellular transmitter, a modem, an application processor, sensors, and an MTPL controller. The mobile device is configured to transmit a signal, or series of signals intended for receipt by the base station utilizing at least one communication standard, such as, for example, Global System for Mobile Communications (GSM), Long-Term Evolution (LTE), Code Division Multiple Access (CDMA), Wideband Code Division Multiple Access (WCDMA), Orthogonal Frequency Division Multiple Access (OFDMA), or New Radio-sub 6 (NR-sub 6).

The base station is configured to transmit a Power Control Level (PCL) to the mobile device. A transmit power level is then determined by the modem of the mobile device based on the received PCL. The upper limit of the transmit power level is generally constrained by an MTPL, which can be adjusted to limit the SAR of the mobile device based on the real-time state of the modem and the device state (e.g., whether the device is positioned against a user's head or body). The application processor can determine the device state based, in part, on sensors disposed in or on the device. From the sensor data and other data available to the application processor, a Radio Frequency Specific Absorption Rate Index (RSI) is generated. The information contained in the RSI is made available to the modem via a specialized interface between the application processor and the modem. In order to determine an MTPL for the device, the modem employs a look-up table to determine the MTPL as a function of the RSI, as well as the radio mode of the device (i.e., LTE, WCDMA, etc.), the band or sub-band at which the device is operating, and the switch state of an antenna associated with the device.

An example RSI is illustrated in Table 1. Ideally, the RSI would include "plus Wi-Fi" device states for each of the device states RSI_2 through RSI_6, resulting in a total of twelve RSI states (including RSI_0 and RSI_1). However, in the present example, the RSI contains only nine device states due to a size limit imposed on the RSI based on feature and chipset planning limitations. Thus, only two device states, RSI_2 and RSI_4, have corresponding "plus Wi-Fi" states (i.e., RSI_7 and RSI_8, respectively) represented in the RSI. The "plus Wi-Fi" device states, RSI_7 and RSI_8, are triggered by a connectivity transmitter (e.g., WLAN or Bluetooth) of the mobile device being in the "on" state. Thus, the system assumes that the mobile device is operating in stand-alone transmission mode when in the RSI_2 and RSI_4 device states and higher MTPL levels can be employed for these states while remaining at or below the SAR limit for the device. However, the remainder of the device states without a corresponding "plus Wi-Fi" state (i.e., RSI_3, RSI_5, and RSI_6) are defined assuming a connectivity transmitter is in the "on" state, regardless of the actual state of the connectivity transmitter. Thus, MTPL levels for these device states are set lower than necessary in order to meet SAR requirements for the device.

RSI	USE CASE
RSI_0	**“Factory Maximum Power”** The maximum available power. This is a stable power value for factory testing that is not subject to changing for Over The Air (OTA) performance reasons.
RSI _1	**“Free Space/ Wireless Charging / Debugging”** Determined by USB Debugging OR wireless charging
RSI _2	**“Head”** Beside the head, (while MCC code indicates 1 g average requirement).
RSI _3	**“Head 10g Region”** Beside the head, while MCC code indicates 10g average requirement.
RSI _4	**“Body”** Against the body, or in hand, while MCC code indicates 1g average requirement
RSI _5	**“Body 10g Region”** Against the body, or in hand, while MCC code indicates 10g average requirement
RSI _6	**“Wi-Fi HotSpot”** Wi-Fi Access Point (i.e. Hotspot Mode), Defined as: (Wi-Fi Hotspot ON) OR (Bluetooth Tethering ON)
RSI _7	“**Head Wi-Fi**” Against the head, AND (Wi-Fi connected OR BT connected OR Wi-Fi Hotspot ON OR BT Tethering ON)
RSI _8	**“Body Wi-Fi”** Against the body, or in hand, while MCC code indicates 1g average requirement, AND (Wi-Fi connected OR BT connected)

Table 1

Some mobile devices are configured to operate in a “dual connection” mode whereby the device receives separate LTE and NR-sub 6 signals and then aggregates the streams. In mobile devices configured for simultaneous transmissions in dual connection mode, SAR measurements are affected by the MTPL for both the LTE and NR-sub 6 transmitters. Consequently, the MTPL for each transmitter is reduced by a set amount, resulting in MTPL levels that are lower than necessary to meet SAR limit requirements. In such cases, it would be beneficial to expand the MTPL look-up table with ten additional “dual connection” device states corresponding to the five stand-alone devices states, RSI_2 to RSI_6, and five “plus Wi-Fi” states corresponding to each of the stand-alone states, resulting in a total of twenty-two RSI states (including RSI_0 and RSI_1). Accommodating an RSI of this size would be significantly costly from a chipset standpoint. In view of the above examples, a method of accurately controlling the MTPL to meet SAR requirements during simultaneous transmission, while employing a relatively compact look-up table would reduce chipset and memory costs.

One approach to reduce MTPL look-up table size in a mobile device, while accounting for simultaneous transmission of a connectivity transmitter and for LTE plus NR-sub 6 dual connection, includes the addition of two offsets in each row of the look-up table. One new MTPL offset (MO_0) corresponds to simultaneous cellular plus Wi-Fi operation, and the other MTPL offset (MO_1) corresponds to dual connection operation. These offsets also allow for reduction of the RSI from nine device states to seven device states, as illustrated in Table 2, since the RSI_7 and RSI_8 "plus Wi-Fi" device states are reflected in the MO_0 offset.

RSI	USE CASE
RSI_0	**"Factory Maximum Power"** The maximum available power. This is a stable power value for factory testing that is not subject to changing for Over The Air (OTA) performance reasons.
RSI_1	**"Free Space/ Wireless Charging / Debugging"** Determined by USB Debugging OR wireless charging
RSI_2	**"Head"** Beside the head, (while MCC code indicates 1 g average requirement).
RSI_3	**"Head 10g Region"** Beside the head, while MCC code indicates 10g average requirement.
RSI_4	**"Body"** Against the body, or in hand, while MCC code indicates 1g average requirement
RSI_5	**"Body 10g Region"** Against the body, or in hand, while MCC code indicates 10g average requirement
RSI_6	**"Wi-Fi HotSpot"** Wi-Fi Access Point (i.e. Hotspot Mode), Defined as: (Wi-Fi Hotspot ON) OR (Bluetooth Tethering ON)

Table 2

The MTPL offset tables provide decibel (dB) unit offsets of the MTPL to reduce the SAR of a device by a precise amount needed during simultaneous transmission to remain within SAR limit requirements. Thus, the MTPL need not be lowered by any more than is necessary to remain within SAR limit requirements. During operation of the mobile device, the MTPL is calculated by the modem from the modified MTPL look-up table according to the following formulas:

1. Standalone Cellular Case: MTPL = Min[MTPL(0),(MTPL(RSI))]
2. Cellular +Wi-Fi Case: MTPL = Min[MTPL(0),(MTPL(RSI)-Offset(1))]
3. Cellular +NR-sub6 DC Case: MTPL = Min[MTPL(0),(MTPL(RSI)-Offset(2))]
4. Cellular +Wi-Fi Case +NR-sub6 DC: MTPL = Min[MTPL(0),(MTPL(RSI)-Offset(1)-Offset(2))]

Calculation of the MTPL is shown in greater detail in Figure 1. Prior to an application interface (API) call, the value of input_RSI, apply_MOS, and pmax_offset have the following default values:

a. input_RSI = 0

b. apply_MOS[3:0] = 0000b

c. pmax_offset = 0.

The cellular MTPL calculation proceeds as according to the following:

MTPL(ant,band) = min [(Network_Pe,max + pmax_offset),

MTPL_Table (ant, band, RSI = 0),

MTPL_Table (ant, band, RSI = input_RSI)

+ MTPL_Offset0(ant,band) * apply_MOS[0]

+ MTPL_Offset1(ant,band) * apply_MOS[1]

+ MTPL_Offset2(ant,band) * apply_MOS[2]

+ MTPL_Offset3(ant,band) * apply_MOS[3].

The MTPL registry look-up and calculation are repeated for UL carrier and must also be repeated each time an API is called with new input values.

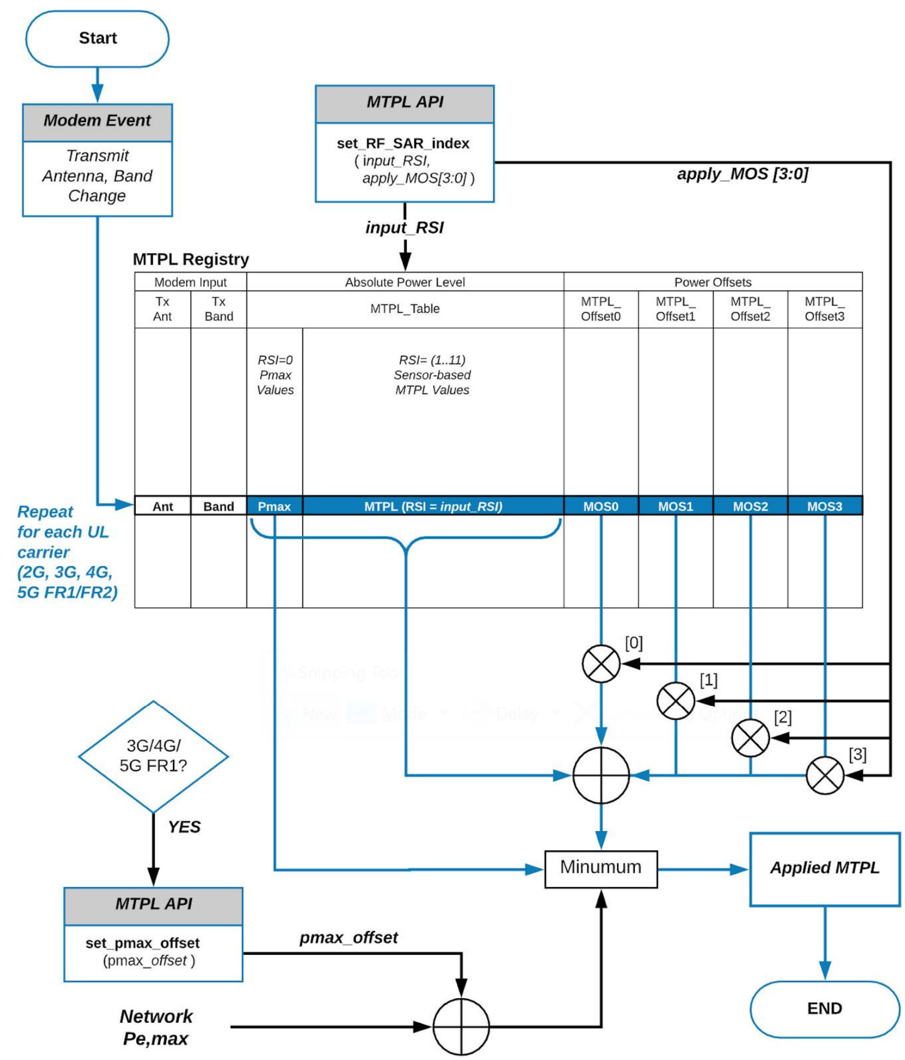

Figure 1

References:

System and method for adjusting a power transmission level for a communication device, U.S. Patent Application Pub. No. 20160157187 (filed Jan. 29, 2016), incorporated herein in its entirety by reference.

Systems and methods for dynamic transmission power limit back-off for specific absorption rate compliance, U.S. Patent Application Pub. No. 20120270592 (filed March 2, 2012), incorporated herein in its entirety by reference.

Method and apparatus for automatic transmit power variation in a wireless communication system, U.S. Patent Application Pub No. 20050143115 (filed Dec. 26, 2003), incorporated herein in its entirety by reference.