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Analysis on Calibration and Uncertainty for TD-LTE Radio Test System

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Abstract: TD-LTE base station radio test system measures radio signal with a required accuracy, so calibration need to be done for transmission path between base station and measurement instruments before test. Considering Transmitter OFF Power measurement within OFF period, modulated signal generator and spectrum analyzer inside test system is used for calibration, to get accurate transmission parameters of the paths, and to reduce test cost without more instruments. The paper describes the uncertainty of test system, analyzes uncertainty contribution of interface mismatch, calculates uncertainty for Transmitter OFF Power measurement, uncertainty is 1.193 dB, within the requirement of 3GPP specification. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Radio test system, Calibration, Uncertainty, TD-LTE base station.

1. Background

TD-LTE base station radio performance test system is applied in research, development and production, it measures transmitter and receiver radio performance [1], network analyzer (NA) is a common instrument for test system calibration before test. On the other hand, the requirement of power within transmitter OFF Power slot is less than -85 dBm/MHz, a special measurement path is designed in test system to meet test requirement, composed of unlinear components like circultor, power limiter and low noise amplifier, this path is unlinear vs. amplitude, and flatless vs. frequency, thus a calibration inaccuracy will happen if NA is used, NA has limits to calibration. A good method is make use of SG and SA within test system for calibration, not only avoiding errors but also instrument costing down.

During test system design, all measurement uncertainty needs to be analyzed and calculated for each radio path, which will be written into result files [2] generated by test system, so as to states accurate base station radio performance. This is a rule for test system design [3]. Test uncertainty is related to radio path and measurement instruments SG and SA. How to find and calculate the uncertainty caused by test system? This article will analyze measurement paths, RF interface mismatch, RF switch repeatability and instrument accuracy, then display the uncertainty formula for Transmitter OFF Power, obtains the uncertainty result at last.

2. Calibration Method and Analysis Method for TD-LTE Base Station Radio Test System

2.1. Radio Paths of TD-LTE Base Station Radio Test System

Radio test system is composed of hardware and software, HW includes computer controller, measurement instruments SG (signal generator) and

SA (signal analyzer) and RF box, shown as Fig. 1, box has RF switches, RF cables, filters, RF attenuator, RF loads and amplifier. Radio paths is made of box and RF cables between base station and instruments, each path could be selected by setting RF switches, need to do path loss calibration, the purpose is to guarantee test accuracy by compensating test result. Box and RF cables connected to it will be regarded as one entire box in next analysis.

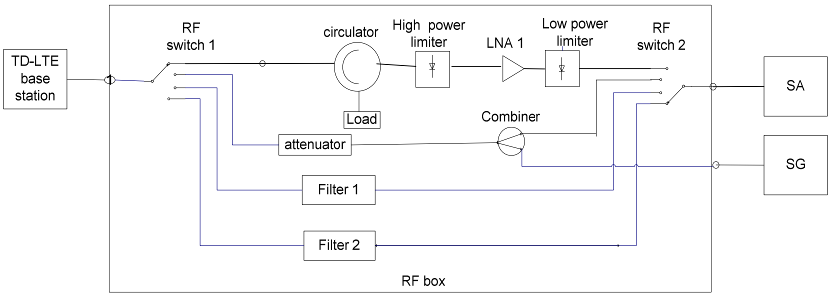


Fig. 1. TD-LTE radio path.

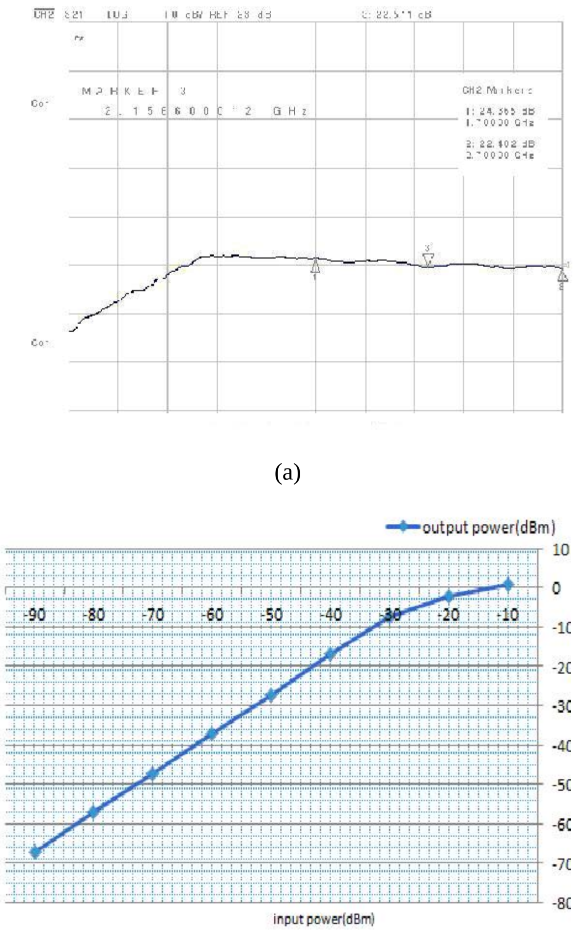
Radio paths is categorized in 4 types here, path A, path B, path C and path D, path A is for transmitter OFF Power measurement; Path B is for transmitter Power ON measurement, spectrum in band, frequency error, EVM and ACLR; Path C is used for uplink signal; Path D measures transmitter spurious emission. Path A is from transmitter output port, via RF switch 1—isolator--high power limiter—LNA—low power limiter—RF switch 2, to SA, which is special for TD-LTE test comparing to other test system.

2.2. Test System Calibration Method

In general, instruments are prepared and configured before test, measure the path loss or gain of radio paths, correct radio path errors, eliminate system errors. This process is called calibration. There are some types of instrument could be for calibration, such as NA, SG, SA and signal receiver. How to choose instrument need to be answered during test system design.

NA is a common instrument for calibration [4], but it has limits to TD-LTE radio test system. NA insensitive signal is CW without any modulation, and its power level range is narrow, meanwhile, it receiver has narrow band, NA calibration may generates error result on a measurement frequency point for a wideband signal measurement, especially calibration on a un-flatness radio path within a signal bandwidth.

Path A has un-linear components isolator, power limiter, LNA, signal level varies within a frequency range, and output un-linear level signal within a level range, shown as Fig. 2, a describes a signal level changing 1.8 GHz within frequency range from 1.7 GHz to 2.15 GHz, b states path A output un-linearity vs. input level range from -40 dBm to 0 dBm in additional OFF Power level requirement is less than -85 dBm/MHz[5], thus calibration incentive signal needs simulating actual OFF Power signal, wideband, modulated, low level LTE signal. LTE modulated SG is a better choice.



(a)

(b)

Fig. 2. Character of path A for TD-LTE transmitter OFF power measurement; A Path A character, un-flatness; B Path A character, un-flatness.

Test system error from path A can be corrected by applying LTE modulated SG and SA in calibration, SG has big signal level range from -120 dBm to +5 dBm, can generate wideband LTE signal, SA has low noise floor, wideband receiver, low level signal measurement [5]. SG connected to input port of path A while SA connected to output port, path A loss could be got by calculating the signal level difference between SG and SA. There is an improved composite instrument combing SG and SA, it can do self-level calibration, correcting SA level with SG level inside instrument, path A loss is got as a relative value which has low uncertainty for calibration.

The calibration process has 3 steps. Setup radio path connection at first, set RF switches in box to path A, connect SG to input port of RF box, while SA connect to output port; then configure instrument parameters, center frequency of SG and SA is same as transmitter center frequency, SG signal is LTE modulated with amplitude level -85 dBm, SA set with minimum internal attenuation, RMS detector, RBW 1 MHz and proper sweep time, read average marker value [6], calculate the path A loss from SG to SA. Repeat the steps above to get the path losses on other frequency points. At last, all path loss values is record into one file, will be for test result compensation while base station test.

To speed up base station radio test, reduce system errors, calibration process is controlled by system test software. Calibration result is saved in one file describing radio path character, test software invoke this file during test, search the right data corresponding to base station frequency, correct test result.

A LabVIEW software module is shown as Fig. 3.

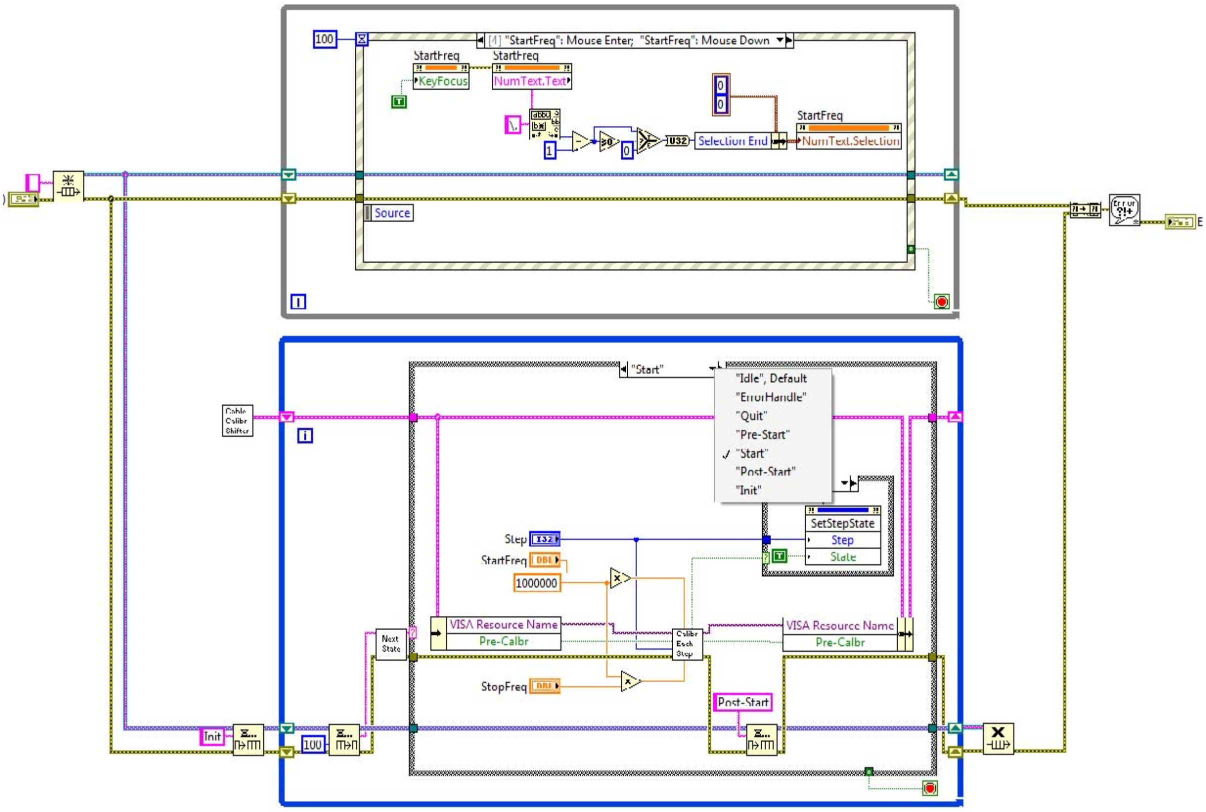


Fig. 3. LabVIEW program for radio path calibration.

Its structure is event structure and state machine, operator instruction is passed to state machine through stack，the calibration parameters is through the property node to the called module. Test action enter stack, as the control input to state machine. State machine invokes different modules [7], such as system initialization, path measurement, exit and so on, and the path selection and calibration is finished in path measurement module which set the instrument, control measurement and read data. Calibration time will be very long for a wide frequency band if only one frequency point is measured in one test cycle, frequency sweep method can improve calibration efficiency. Composite instrument output a frequency sweeping LTE signal according to frequency raster for TD-LTE, and SA read trace RMS data with setting of trace hold function for a wideband in once time, there is no calibration cycle for one path, calibration time is shorten largely.

2.3. Test System Uncertainty Analysis

To calculate the test system's uncertainty, set up uncertainty model firstly, then analyze the influence factors of the specific path and calculate results.

2.3.1. Uncertainty Model for Test System

There is a common mathematic model for system uncertainty [7] as following:

$$Y \pm U = X_1 \pm u_1 + X_2 \pm u_2 + \ldots + Xi \pm u_i,$$

where Y is the output of a path, U is the system uncertainty to be got, X_i is the input parameter of different components, from the measured signal, a cable or the loss of equipment, u_i is input uncertainty parameters of components. The uncertainty of calibration is a component uncertainty.

A method for uncertainty, Type A, require different environmental conditions of temperature and humidity on the system calibration, need regular measurement for system, a series of data are obtained, system uncertainty is statistic on these data. Type A is time consuming, another method is Type B, relatively simple, describe how to use the Type B method to calculate uncertainty in test system.

System uncertainty formula for Type B [8]:

$$U = ku(y) = k\sqrt{(c_1u_1)^2 + (c_2u_2)^2 + \ldots + (c_iu_i)^2}$$

Test the uncertainty of the system considering several factors: the confidence factor k, sensitivity factor of C_i, u_i is uncertainty factors from components, including instrument specification, device measurements uncertainty, radio path interface mismatch, and so on.

2.3.2. Test System Uncertainty Calibration with Condition of SG and SA

The Type B uncertainty model based on the consideration of some factors, radio path connections and the influence of RF components, different uncertain calculation formula is for different path. For measurement of ACLR, EVM, OBW and frequency error of base station, transmit parameters of radio path does not affect the test results, uncertainty of the system only considers SA brings uncertainty, and the calibration contribution to uncertainty can be ignored, this article no longer has too much description for these test cases. For TD-LTE base station transmission time slot power measurement, Power ON/OFF measurement, a concrete analysis of path A need to do. According to EA-4/02[2], first look at the interface mismatch uncertainty Eq. (1):

$$Mismatch_{Equip-box} = \frac{10^{(EquipS11/20)} \times 10^{(boxS11/20)} \times 100}{11.5} \quad (1)$$

Mismatch Equip-box, uncertainty caused by interface mismatch between Equi and BOX, has U distribution. Equip may be DUT base station, SG or SA.

Second analyze the calibration uncertainty Eq. (2):

$$Cal_{uncert} = k\sqrt{\begin{array}{l}(\frac{SG_{uncert}}{\sqrt{3}})^2 + (\frac{SPA_{uncert}}{\sqrt{3}})^2 + (\frac{\mathrm{Re}\,peat_{switch}}{\sqrt{2}})^2 \\ + (\frac{Mismatch_{SG-box}}{\sqrt{2}})^2 + (\frac{Mismatch_{SPA-box}}{\sqrt{2}})^2 \\ + (\frac{Mismatch_{SPA-SG}}{\sqrt{2}})^2\end{array}}, \quad (2)$$

RF switch repeatability Repeatswithch has Gaussian distribution, level uncertainty from SG or SA specification has a rectangular distribution, interface mismatch uncertainty has U shape distribution [8].

Finally, let's analyze the uncertainty of OFF Power path A in test system. Same SA is used for calibration and base station measurement, and same setting for both; SA repeatability has little contribution, to be ignored. So the system uncertainty, only consider the mismatch between DUT and BOX, and calibration uncertainty. 3GPP requirement of probability is 95 % [9], factor k=1.96, we get the Eq. (3) for system uncertainty.

$$U = 1.96\sqrt{(\frac{Mismatch_{DUT-BOX}}{\sqrt{2}})^2 + (\frac{Cal_{uncert}}{\sqrt{3}})^2}, \quad (3)$$

3. Result Analysis

Considering the use of SG with modulated signal and SA on calibrating, now calculate the measurement uncertainty for Power OFF. According to the instrument manufacturers specifications, and some interface measurement data, the input parameters are shown in Table 1.

Table 1. Input parameters for uncertainty calculation for path A.

	Specification data	Measurement result
SG	SG_{uncert}=0.5 dB[10]	SGS11= -20.1 dB
SA	SPA_{uncert}=0.5 Db[10]	SPAS11= -20.6 dB
BOX	No	BOXS22= -16.1 dB BOXS11= -18.1 dB BOXS21= -40.1 dB BOXS12= -80.5 dB Repeatswitch= 0.015 dB
DUT	no	DUTS11= -16.8 dB

Calculate RF interface mismatch based on Eq. (1):

$$Mistmach_{DUT-BOX} = 0.1564\ dB$$
$$Mistmach_{SG-BOX} = 0.1070\ dB$$
$$Mistmach_{BOX-SPA} = 0.1272\ dB$$
$$Mistmach_{SG-SPA} = 7.5 \times 10^{-8}\ dB$$

Therefore, according to the Eq. (2), path A calibration uncertainty Cal_{uncert}=0.861 *d*B, TD-LTE OFF Power measurement uncertainty is got from Eqs.(3), U=1.193 *d*B <2.0 *d*B (<3 GHz),which meet 3GPP requirement of OFF Power measurement uncertainty[1].

4 Conclusions

Measurement path of TD-LTE radio test system need to be calibrated before testing, for its special path to satisfy OFF Power measurement, calibration input is broadband modulation signal -85 dBm/MHz to avoid system error, the selection of modulated signal source and the spectrum instrument for calibration, not only solve the calibration problems, but also save the cost of purchasing instrument. This paper analyzed several factors affecting OFF Power measurement, radio path structure, interface mismatch and RF switch repeatability, instrument specification, the calibration method, calculated measurement uncertainty for OFF Power, a typical of TD-LTE OFF Power measurement uncertainty is 1.193 dB, meet the test requirements.

Acknowledgments

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