EMF measurements on LTE signals using the R&S®TS-EMF portable system

The R&S®TS-EMF is a portable system for measuring electromagnetic fields in the environment (EMF). It has proven successful over many years of use by government authorities and measurement service providers while undergoing continuous development to keep pace with technology. A new software update is now available for this system to make measurements on the signals used in the LTE mobile radio networks that are starting up worldwide.

Well suited for LTE

The tried-and-tested R&S®TS-EMF portable system for EMF measurements (FIG 1) is used to verify compliance with applicable limits. It covers all relevant measurement methods. This includes, for example, the GSM, WLAN and WiMAX™ radio standards as well as decoding of the CPICH in WCDMA. The system measures all signals from the broadcast to the mobile radio and radar ranges and sums them up. It also performs extrapolations to determine the maximum utilization of mobile radio systems, for example.

The LTE mobile radio networks that are currently set up in many countries are making it necessary to take this new mobile radio standard into account as part of EMF measurements. Accordingly, the R&S®TS-EMF portable system has been expanded to include LTE-specific functions based on the latest research in this sector.

LTE signal structure

LTE uses an OFDMA signal with a bandwidth of up to 20 MHz and made up of a number of subcarriers that are 15 kHz wide. In addition, it has a timing structure with a frame length of 10 ms consisting of 10 subframes and a symbol length of 71 µs.

In the band center, this signal contains 1080 kHz wide signaling in addition to the user data. The P-SCH and S-SCH channels (also known as S-Sync and P-Sync) are encoded individually per base station and are transmitted with constant power so that, analogous to decoding of the CPICH, an individual correlation between the emission and the base station is obtained. The same applies to the reference symbols which are distributed over the entire spectrum (FIG 2).

FIG 1 Precision EMF measurements on LTE signals: the R&S®TS-EMF portable system with the R&S®TSEMF-B2 isotropic antenna and the R&S®TSMW universal radio network analyzer.

All other channels, including the user data, are not encoded. Accordingly, adjacent base stations coordinate the allocation of timeslots and frequency channels with flexible timing. This is a distinction compared to WCDMA where all channels are encoded. In addition, different modulation types are possible per time and frequency block in LTE.

Spectrum of an LTE signal

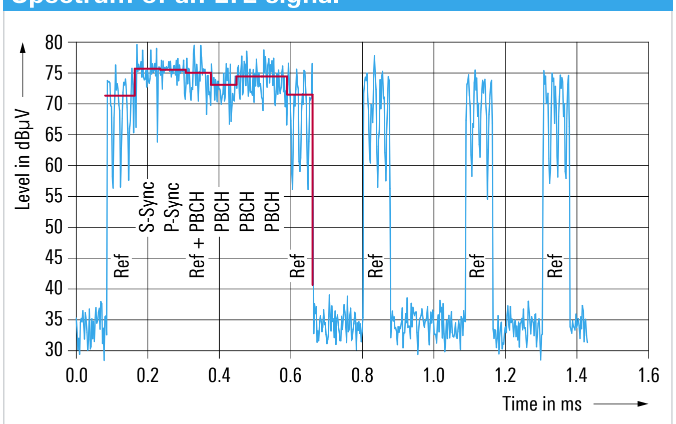

FIG 2 LTE signaling without user data.

Frequency-selective measurement

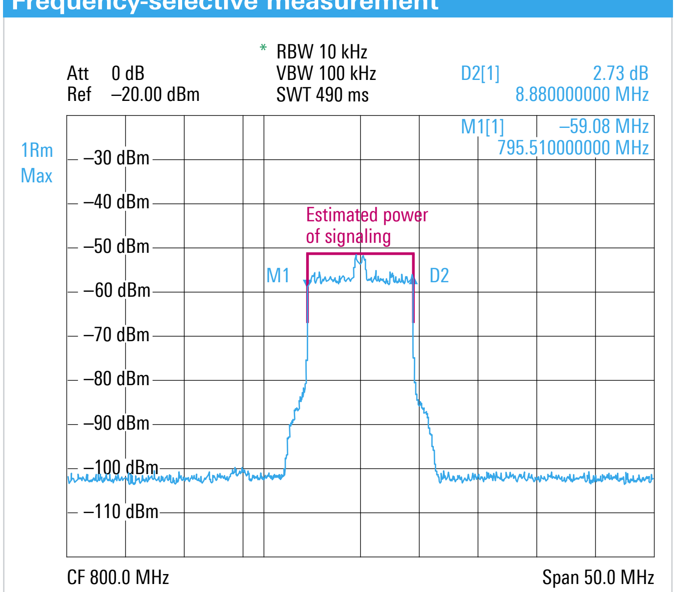

FIG 3 Frequency-selective measurement on an LTE signal without user data.

Frequency-selective measurement

The R&S®TS-EMF does not require any expansions to perform frequency-selective measurements on LTE signals. Such measurements determine the instantaneous total field strength generated by all surrounding base stations (FIG 3). Due to the high crest factor, the RMS detector must be used. However, because of the signal's timing structure, the dwell time per measurement point must be optimally adapted to the symbol rate in order to avoid undervaluation or overvaluation. The test system provides diverse measurement capabilities:

- Average power versus signal bandwidth
  This measurement shows the fluctuations that occur due to varying network utilization. Since the reference channels are distributed across the entire frequency range, the signal bandwidth can also be determined in this manner.
- Field strength due to signaling in band center
  Since the signaling level and the reference symbol level can be set independently, extrapolation requires appropriate specifications from the network operator.

For frequency-selective measurement of LTE signals, the latest R&S®TS-EMF software version (RFEX v6.1.30) has been expanded to include test packages with predefined parameters for LTE. This makes it very convenient to measure LTE signals, especially in combination with the R&S®TSEMF-B2 isotropic antenna that covers all LTE bands with its frequency range from 700 MHz to 6 GHz.

Frequency-selective measurements can only determine the total value for all surrounding base stations. It is not possible to correlate the results with individual base stations. Like in WCDMA, it is necessary to apply large safety factors when extrapolating to the maximum system utilization. On the one hand, this is due to the fact that, depending on the base station settings, user data can cover the signaling, making the measurement result a function of the traffic. On the other hand, multiple input multiple output (MIMO) technology is used in LTE. Here, user data is transmitted via up to four antennas while the signaling is sometimes transmitted only via one antenna. Accordingly, the other propagation paths are not taken into account for the signaling. A third issue is that the LTE standard allows transmission of signals to individual user equipment with a level that is up to 3 dB higher.

Code-selective measurement

For WCDMA, it was already shown that precise extrapolation to the maximum utilization and correlation of the emission with a base station are possible only by decoding the signal. The situation is comparable with LTE. Precise extrapolation is based on the signaling field strength or alternatively on the reference symbols. However, detailed base station parameters are needed such as the number of channels or the factor ρ_B that represents the ratio of the signal levels. These signal

Packet: LTE Test

Cell ID	Frequency [MHz]	Field Strength E [V/m]	Field Level [dBµV/m]	Limit L [V/m]	Exposure Ratio ER E² / L²	ER * 1000 [‰]	Power Density [µW/cm²]
255	796.0000	0.0755	97.5593	38.7999	0.0000	0.0038	0.0015
3	806.0000	0.1412	102.9984	39.0429	0.0000	0.0131	0.0053
	Total Exposure Ratios				0.0000	0.0169	0.0068
	Total Field Strength (RMS)		0.1601 V/m				
	Max. Single Value:		0.1412 V/m				

Cell ID	S-SyncChanPow [V/m]	P-SyncChanPow [V/m]	CenterRSRP [V/m]	AntMaskRSRP
255	0.075502746	0.075502746	0.007763598	1
3	0.141389867	0.141389867	0.014613444	1

Antenna:	Tri-axis probe
Cable:	0 m Cable
Limit Line:	ICNIRP
Extrapolation factor:	0 dB

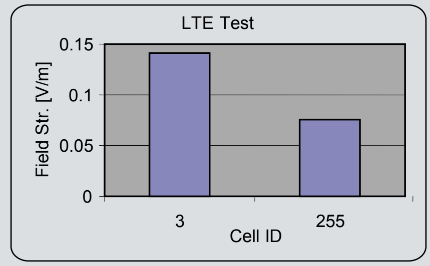

FIG 4 Example of a test report for LTE decoding.

	LTE	WCDMA (UMTS)	GSM
Modulation method	OFDMA	CDMA	FDD-TDMA
Distinction between base stations	code	code	frequency
Signaling	symbols in specified timeslots in band center	CPICH, constant amplitude	BCCH, constant timing
Signaling power	variable with respect to max. power (typ. ≤ ±3 dB)	variable, typ. 10 % of max. power	BCCH always full power
Influence of user data	power on additional subcarriers and / or timeslots	boosting of signal with additional power	traffic channels on different frequency channels
Measurement method	decoding of six inner resource blocks: P-SCH, S-SCH, reference symbols and cell information	decoding of CPICH	power level of BCCH, no decoding
Extrapolation to max. power	level of reference symbols extrapolated to full bandwidth	max. power / CPICH power	max. number of TCHs
MIMO	yes	no	no

FIG 5 Measurement methods in LTE, WCDMA and GSM.

parameters are automatically determined during decoding. In the area of MIMO, the measurement makes it possible to determine by how many antennas the received reference signal was transmitted, allowing an exact extrapolation.

These code-selective measurements are supported by the R&S®TS-EMF portable test system in conjunction with the R&S®TSMW universal radio network analyzer and the R&S®TSEMF-K21 and R&S®TSMW-K29 options. The high measurement speed supports all relevant measurement methods including stirring, dot matrix and averaging versus time. Accordingly, the tried-and-tested WCDMA measurement method has been expanded to cover LTE. The system can output a detailed test report at the press of a button (FIG 4).

Summary

The R&S®TS-EMF is the first EMF test system to support frequency-selective and code-selective measurements on LTE-FDD signals. While the frequency-selective measurement determines the instantaneous total emissions from all surrounding base stations, the code-selective measurement enables correlation of the emissions with individual base stations and precise extrapolation to the maximum utilization. Using this proven method from WCDMA applications, overvaluations or undervaluations are avoided to deliver a realistic assessment with the necessary precision.

FIG 5 compares measurement methods for the different mobile radio standards.

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