RF Testing on Automotive Infotainment Devices

Application Note

Products:

- R&S®BTC
- R&S®CMW500
- R&S®SMBV100A

What used to be the car radio has evolved from adding a cassette player to state of the art entertainment on the move. All this while keeping driver & passengers connected. The design challenge is to bring all the communication and broadcast standards into a small form factor that fits in the dashboard of the car. The RF modules need to support multiple standards in a single assembly and multiple modules are placed next to each other. The frequencies defined by the RF standards are in very close proximity and hence need to co-exist with each other. Moreover, the antennas inside the car are subjected to cross-coupling effects with mobile devices of passengers. To ensure the RF performance of the infotainment system, all of these scenarios need to be thoroughly tested.

This application note highlights some of the RF measurement challenges and introduces Rohde & Schwarz equipment required for relevant RF characterization of car infotainment devices.

Note:

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Application Note
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5.2017 – 1MA275_2e

ROHDE&SCHWARZ

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1 Abstract

The evolution of in-car entertainment has been fast-paced. The first in-car audio system supported an AM radio and dates back to the 1930s. From 1952 and onwards, FM and eventually an 8-track or cassette player started to become the norm in most cars. Then came car entertainment systems adding cable connection of a cellular handset and playback of video from VCD or DVD. Simple navigation was the next big step. But even those days are long gone. Some of the functions of past have survived the test of time while some became more evolved and complex. Car infotainment systems now offer much more information and functionality to drivers and, increasingly, passengers. This has introduced many design challenges. Nevertheless, it is worth the trouble, since the added value offers more luxury, ensured comfort and a lot of additional assistance.

It is quite interesting how this evolution resembles the evolution of portable phones to smartphones. The good old car radio has justifiably been rebranded as the car infotainment system, entailing a bunch of new functionality onboard. Some of the functionalities include listening to satellite radio, connecting passengers inside the car to the internet via a WLAN hotspot, watching television, using the navigation system to find a nearby restaurant, play music from a smartphone via Bluetooth or just stream video on the infotainment device itself while being in motion. All this capability is made possible by the increase in (RF) hardware and software complexity of the infotainment devices. From an RF point of view, some of the radio standards operate in very similar frequencies, and need to be tested for co-existence issues. The number of antennas to support all the RF standards have increased. Antenna cross coupling becomes another source of complication and degrade the overall performance of the system. And finally, passenger's own gadgets brought inside the car may lead to complex interference scenarios that may have a lot of impact that warrants testing.

Transmission Standards		
	Video & Audio	DVB-T & DVB-T2
		ISDB-T
		DTMB
		DAB
		Sirius / XM Radio
		AM/FM
	Navigation	GPS
		GLONASS
		Galileo
		BeiDou
	Wireless	WLAN
		Bluetooth
	Cellular	LTE-A
		LTE
		HSPA
		WCDMA (3G)
		EDGE
		GSM (2G)

The RF standards that are supported in modern automotive infotainment device are shown in the table. All these standards are working over a frequency range up to 6 GHz closely beside each other.

This application note will aim to introduce the possible testing methodology of the RF standards for functionality, co-existence and cross-coupling measurements using Rohde & Schwarz (R&S) Equipment.

Abbreviations

The following abbreviations are used in this application note for Rohde & Schwarz products:

- The R&S®BTC Broadcast Test Center is referred to as BTC
- The R&S®CMW500 Mobile Radio Platform is referred to as CMW
- The R&S®SMBV100A Vector Signal Generator is referred to as SMBV
- The R&S®CMW-Z04 Mini-UICC/USIM Test Card is referred to as Test SIM
- The car infotainment Device Under Test is referred to as DUT

2 RF Design and Measurement Challenges in Infotainment Systems

The evolution of the automotive infotainment systems not only features the combination of a car radio and a car navigation system but also a digital television, an internet modem, a smart phone (Bluetooth, WLAN, LTE, 3G etc.) and more. The challenge is the dashboard fit requirement and antenna placement. Hardware supporting completely different standards may be designed on the same chip or on multiple chips assembled side by side. As spectrum is limited, many of these standards operate quite close to each other. Table 2-1 shows the RF standards and their corresponding operational frequency.

Reference	Standard	Remarks	Frequency
1	FM		87.5 MHz - 104 / 108 MHz (regional differences)
2	DVB-T/ T2	Channel 2 to 83	54 MHz - 694 / 786 / 890 MHz (regional diff.)
3	ATSC	Channel 2 to 51	50 MHz - 698 MHz
4	Sirius/XM Radio		2320 MHz - 2345 MHz
5	WLAN	IEEE802.11 b/g/n	2412 MHz - 2484 MHz and 5180 MHz - 5825 MHz
6	Bluetooth		2400 MHz - 2485 MHz
7	LTE + LTE Advanced	**Depends on band**	700 MHz - 3800 MHz
8	WCDMA/ 3G	**Depends on band**	700, 800, 850, 900, 1500,1700,1800,1900,2100,2600, 3500 MHz
9	AM		535 KHz – 1605 KHz
10	DRM		Band I (47 to 68 MHz), Band II (87.5 to 108 MHz) and Band III (174 to 230 MHz)

Table 2-1: Different standards and corresponding operational frequency [1][2][3][4][5][6][7][8][9][10]

From the table, it is quite clear that the communication standards have significant proximity and even in some cases overlap in spectrum. Most critical frequency overlapping of standards are between Bluetooth and WLAN, LTE or 3G with Bluetooth or WLAN, and LTE or 3G with Digital TV (DTV). For LTE and 3G-WCDMA, only a few selected bands are simultaneously used in a given area. The implemented bands depend on regions, countries and government regulations. The infotainment device do not support all the bands in a given target market. So the chances of a co-existence problem arising seemed slim so far. However, infotainment devices do support an increasing number of bands as national regulators open up more spectrum and/or a given device is used for several target markets to bring down cost of the radio subsystems.

Adjacent channel interference is another potential problem that needs to be considered. For bands located close to each other in spectrum a wanted signal is degraded because of poor power control and/or inadequate transmit or receive filtering. Clearly, all supported standards need to function in all supported modes of operation, hence a full co-existence characterization is an extensive field of work that can be separated into two tasks, a) the characterization of the dashboard unit itself, and b) performance verification of the antenna subsystem that feeds the dashboard unit.

Typically, the antenna feeds carry a DC supply that enables local signal pre-conditioning at or near the antenna mounting position. Establishing the needed performance gains of the remote antenna subsystem (i.e. gain, filtering) is best achieved by characterizing the dashboard part of the infotainment system first, thereby establishing the minimum requirements on the remote antenna subsystem, and then repeating the tests in radiated mode on the whole car in a suitable environment.

On top of the co-existence problem, the infotainment system needs to be functional not only when the car is static but also when in motion. Signals undergo fading effects not limited to basic Doppler. Full functional testing under drive conditions for the complete set of likely outdoor scenarios should ideally be replaced by radio channel emulation as a cost-effective, measurement instrument based alternative to drive tests. This integration also takes away the repeatability issues of any outdoor drive testing.

By including RF channel emulation into the standard-conform signal generator, R&S instruments avoid calibration challenges of any external channel emulators. Accuracy and repeatability are improved even further being connected using a well-defined internal digital connection instead of the common analog baseband interface.

3 Test Methodology

This section is divided in three sections. The first section would explain how to perform functionality tests on the infotainment system (DUT). The second section introduces the wired test setup for multi-standard co-existence characterization and an example measurement. The third section shows an Over-The-Air (OTA) antenna cross-coupling and co-existence measurement setup and an example for a radiated test is discussed.

3.1 Functionality Test on Infotainment Systems

Functionality test for all of the standards mentioned in Table 2-1 needs to be performed individually at first. The test setup in Fig. 3-1 shows the Rohde & Schwarz equipment used for testing the DUT.

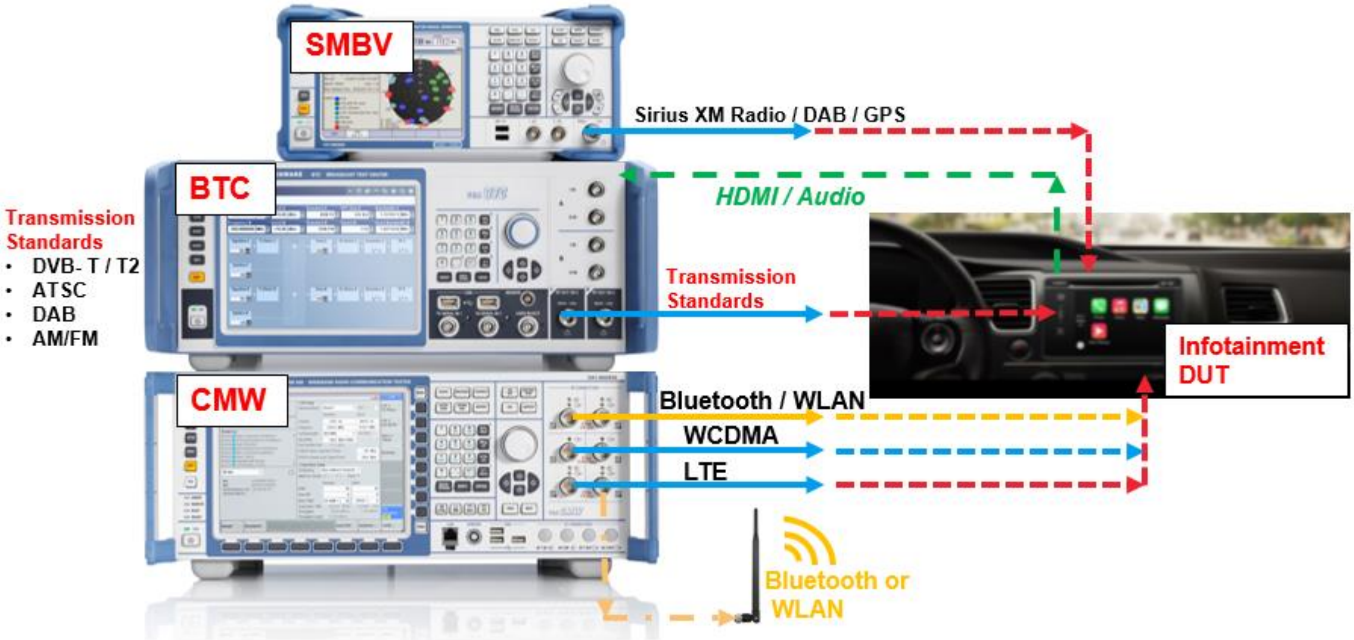


Fig. 3-1: Test setup for automotive infotainment RF characterization

The BTC is used to generate audio and video signals such as AM, FM, DAB, DVB-T/T2, ATSC, DAB, Sirius / XM Radio and the CMW is used to generate Bluetooth, WLAN, WCDMA/HSPA and LTE radio signals. BTC or SMBV may provide satellite standards SDARS (Sirius / XM) and DAB while SMBV simulates GNSS signals such as GPS, GLONASS, BeiDou and Galileo. Due to the scope of this application note the examples have been limited to use of BTC and CMW.

The output ports of the test instruments are connected directly to the antenna ports of the DUT. Normally, the Bluetooth and WLAN antenna on the DUT is not accessible and in that case the Bluetooth and the WLAN signaling from the CMW needs to be made over the air using an appropriate antenna. In addition, in order to perform video quality testing, the DUT HDMI output connects to the BTC HDMI port. Some infotainment systems (like the DUT used in this AN) do not have an HDMI output. An alternative test method is suggested below.

Another important pre-requisite in order to perform LTE or 3G measurements on the DUT is a Rohde & Schwarz Test SIM which must be inserted into the DUT SIM slot.

3.1.1 RF Signal Generation using the BTC

The BTC broadcast test center is a reference RF signal generator featuring analysis functions and automated tests for audio, video and multimedia applications. It is a unique combination of outstanding technical features and a modular, flexible design to meet the highest demands and latest transmission technologies.

The BTC is a high-end RF signal generator, it generates RF signals for all global broadcasting standards, performs transmission simulation and, at the same time, makes audio and video analyses for the DUTs. All this is made possible by using diverse interface, generator and analysis modules.

Due to its extremely fine scalability, the BTC can be tailored to meet different customer and test requirements while simultaneously optimizing costs. This eliminates the need for expensive and time-consuming test setups with many separate Test & Measurement (T&M) instruments.

3.1.1.1 Generating a DVB-T/T2 signal with BTC

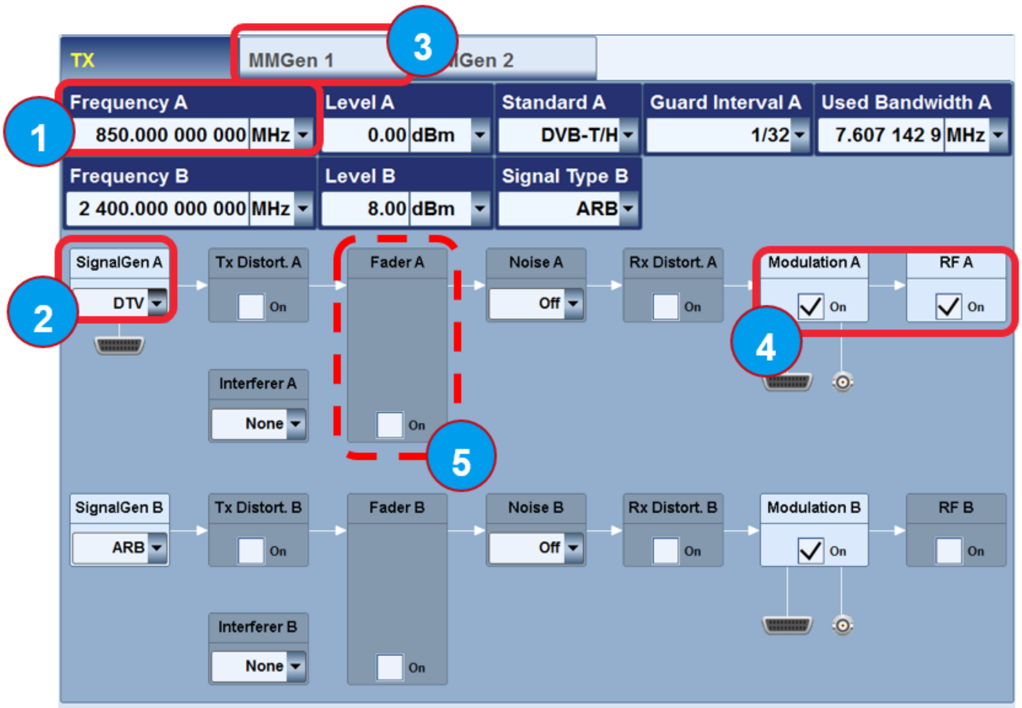


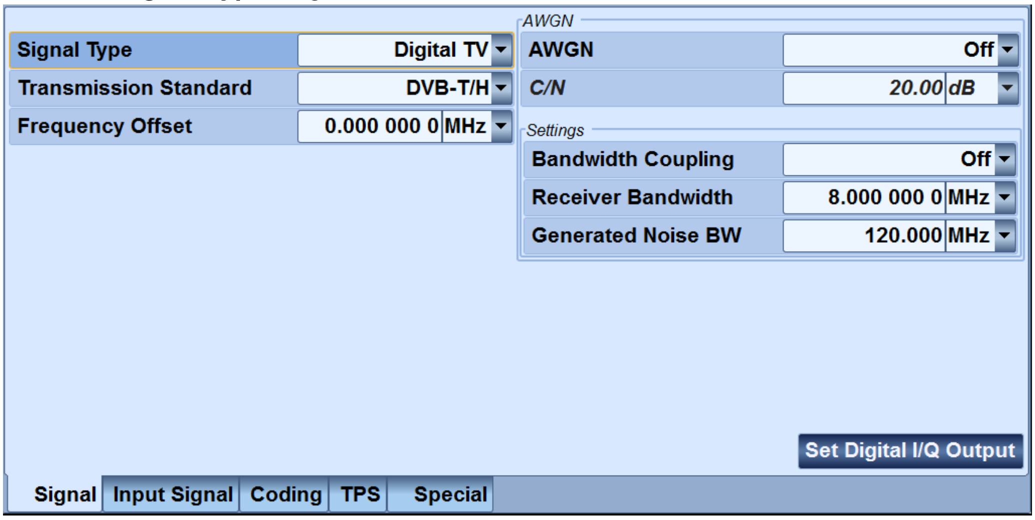
Fig. 3-2: List of steps to generate DVB-T/T2 signal on the BTC

Step 1: As shown in Fig. 3-2, select the frequency at which the DVB-T/T2 signal needs to be generated. Normally, set the center of the channel as the transmit frequency on the BTC. For this example, we want to transmit on channel 68, which spans from 846 MHz - 854 MHz. Therefore, we set 850 MHz as the transmit (Tx) frequency.

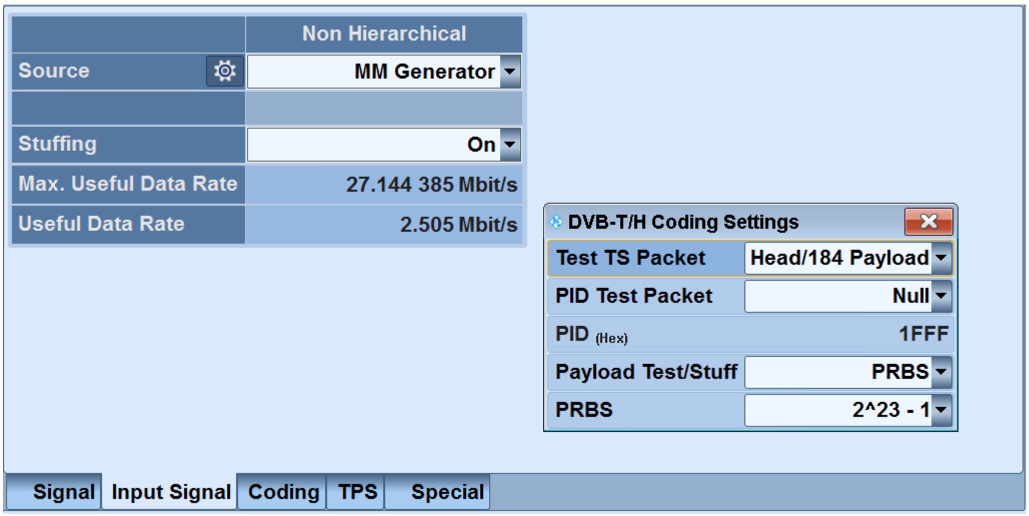
The digital dividend usually locates at frequency bands from 174 to 230 MHz (VHF) and from 470 to 862 MHz (UHF). However, the location and size of digital dividend vary among countries due to the factors including geographical position and penetration of satellite/cable services. Many countries are in favor of using a part of the digital dividend for electronic communications services, such as mobile communications and wireless broadband. These new services would utilize the upper part of the UHF band (790-862 MHz) [11]. The selection of frequency is therefore made based on test requirement.

Step 2: As shown in Fig. 3-2, double click on *SignalGen A*. Configure the parameters as shown in the picture below

- **Signal Type:** Digital TV and desired Transmission Standard

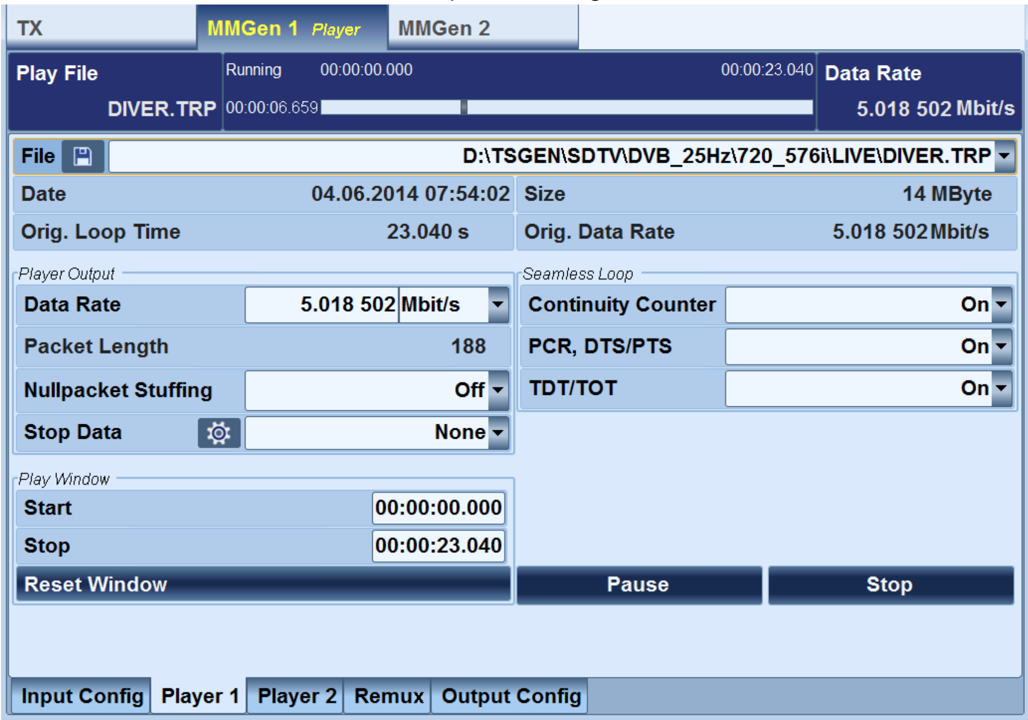


- Next Select : Input signal and configure as shown in the picture below
  - **Source:** *MM Generator*



Step 3: As shown in Fig. 3-2, click on *MMGen 1* and then go into *Player*

- Select the File titled “Diver.trp” and configure as follows.



Step 4: As shown in Fig. 3-2, switch on *Modulation A* and *RF A*

At this point, the signal from the BTC is properly configured and transmitting. Now connect the output of the BTC RF A to the input on the DUT. On the DUT, go in to the TV tuner menu and scan for available channel list from the appropriate standard (DVB-T/T2). After the channel is found, select the channel with the name “Diver”.

Fig. 3-3: Test video from BTC using BTC played on the DUT

Fig. 3-3 shows a test video transmitted from BTC using DVB-T2 standard on channel 68 which the DUT is tuned to. *The DUT used in this example does not have any HDMI* *output.* Therefore, a visual inspection of use of a software observation connected to a camera may be used to detect performance degradation.

The functionality test for when the car is static was described up to this point. Next, in order to perform test for non-static scenario, double click on *Fader A* from Fig. 3-2.

Step 5: configure the parameters as shown below

- Fading : On
- Profile: as required (For this example, *Pure Doppler* is selected)
- Speed : as required (For this example, *220 km/h* is set)

[Fig. 3-4](#) shows degradation of the receive signal quality when the Fader is switched on. The picture marked as **1**, is before switching on the Fader on the BTC. Picture marked **2** and **3** are after the *Fader* is switched on. This is a visual assessment of the receive quality of the DUT. A DVB-T/T2 tuner intended for infotainment devices need to be designed and optimized so that it is capable of handling Doppler and speed variation.

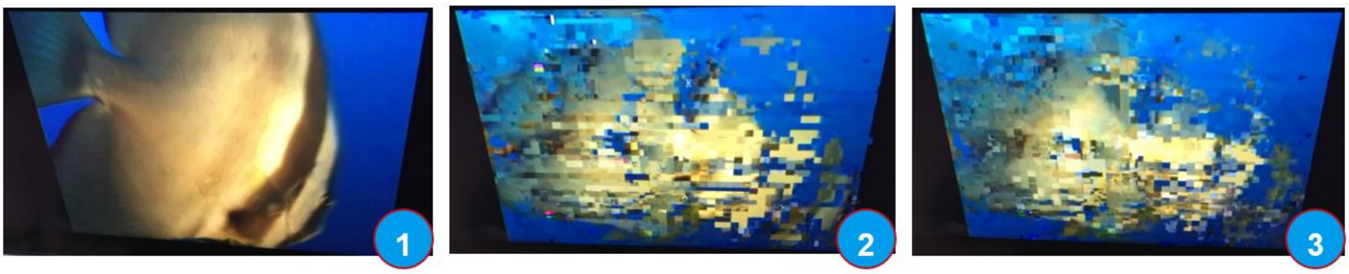


Fig. 3-4: Degradation of signal receive quality on the DUT as the fader is switch on in picture 2 and 3

3.1.1.2 Additional RF Signaling Possibilities with BTC

From Fig. 3-2, double click on the Interferer A.

It is possible to set up to **8** interferer signals of different standards in parallel to the wanted signal on the BTC, as shown in Fig. 3-5.

Arbitrary Waveform Generator

Generator	1	2	3	4	5	6	7
State	On	On	On	On	On	On	
Usage	Interferer	Interferer	Interferer	Interferer	Interferer	Interferer	Inte
Waveform[.wv]	FM_SMAL_75KHZ	HD_FMr208c	DRM_-12dBFS	DAB_351	DVBT2_SF12	ISDB-TSB_3SEG	LTE_UE_10Mb
Required Option	WV-K816	WV-K804	WV-K803	WV-K801	WV-K809	WV-K1114	
Samples /MS	0.001	4.424	15.581	1.573	59.505	3.760	
Sample Rate /MS/s	1.000 000	0.744 188	0.024 000	4.096 000	11.428 570	16.253 970	16.66
Sequence Dur. /s	0.001	5.944	649.200	0.384	5.207	0.231	
Attenuation /dB	10.00	16.00	10.00	13.00	-3.00	14.00	
Freq. Offset /MHz	-50.000 000 0	-40.000 000 0	-30.000 000 0	-16.000 000 0	16.000 000 0	30.000 000 0	40.000

Fig. 3-5: Up to 8 interferer signals played using the built in Arbitrary waveform Generator on the BTC

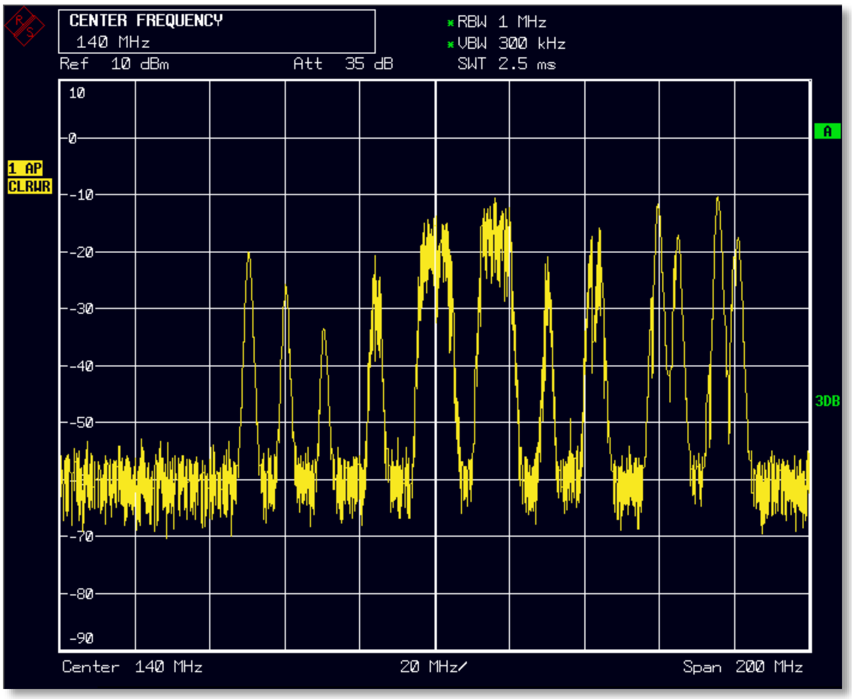


Fig. 3-6: Frequency spectrum of 8 interferer signal outputted from the BTC

Fig. 3-6 shows spectrum of eight interferer signals (as configured in Fig. 3-5) loaded to the Arbitrary Waveform Generator (ARB) of the BTC.

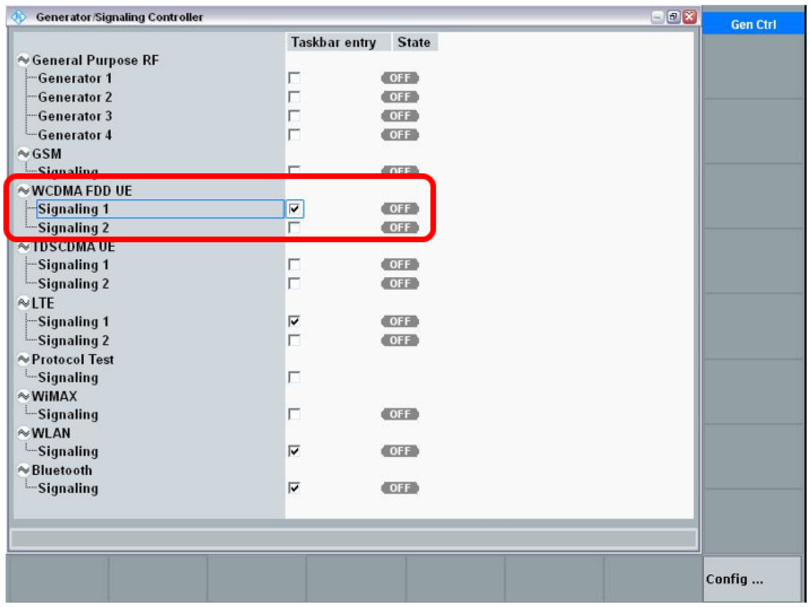
3.1.2 Signal Generation using the CMW500

The CMW500 communication tester for testing the air interface of wireless devices. It supports the testing of cellular, wireless connectivity, satellite navigation and broadcast technologies.

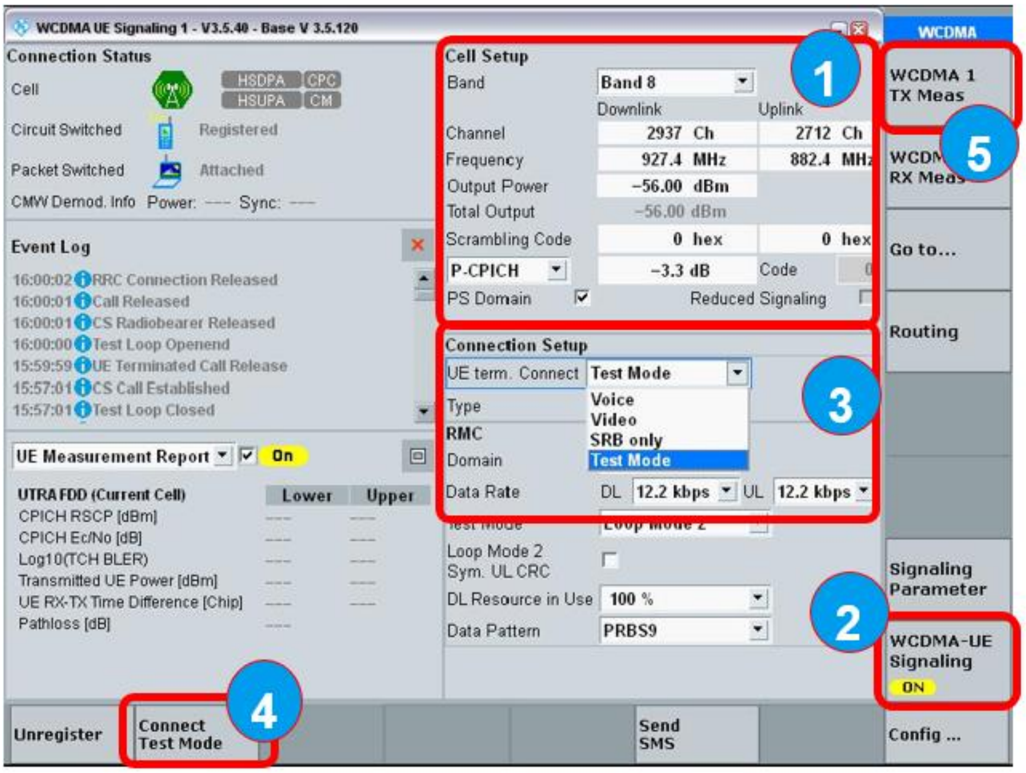
As a pre-requisite of using the CMW in order to perform signaling and testing on the DUT, insert the Rohde & Schwarz Test SIM into the DUT SIM slot.

3.1.2.1 Generating a WCDMA or LTE signal with CMW

- Connect the instrument to the DUT as shown in Fig. 3-1.
- On the CMW click on the **Signal Gen** button and enable WCDMA Signaling 1 as shown below

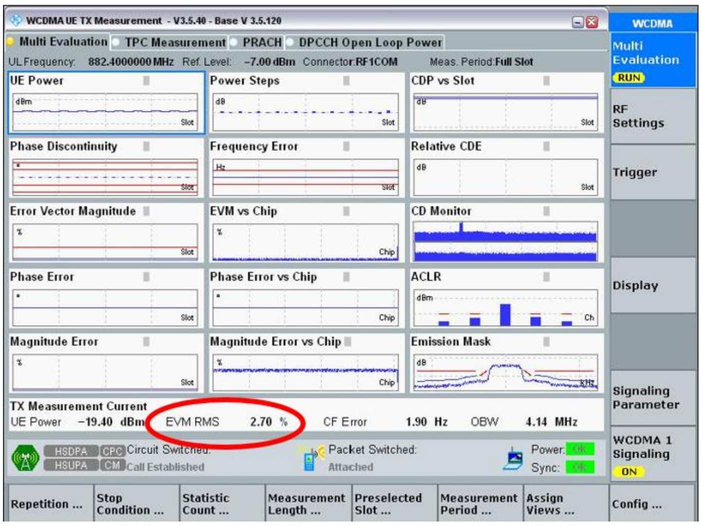


- Next enter the WCDMA FDD UE Signaling 1 Menu



- Step 1:
  - Select the required band (e.g. Band 8)
  - Setting a higher output power level eases the DUT connection and registration
- Step 2:
  - Switch CMW WCDMA-UE Signaling ON
  - Navigate to the DUT network setting and manually select R&S Test Sim network. Normally, the network is automatically selected by a DUT with Android or IOS operating system. Make sure the Test SIM is also used as the main connection for data and telephone on the DUT
- Step 3
  - On the CMW select the type of connection required for the measurement from the drop down menu. (Test Mode in this example)
  - If Voice is selected, a phone call would be initiated from the CMW to the DUT. Please accept and answer the call on the DUT
- Step 4 & Step 5
  - *Connect Test Mode* by clicking on it
  - After connecting successfully, go into the WCDMA TX Measurement window

- Switch ON Multi Evaluation and measure the signal's EVM (Error Vector Magnitude), here 2.70%.



3.1.2.2 Additional Signaling Possibilities with CMW

Similar to the examples described in the previous two sections, LTE, WLAN and many other signals can also be easily generated and the DUT functionality tested.

Fig. 3-7 shows a list of relevant standards required for testing and future proofing car infotainment systems with the CMW.

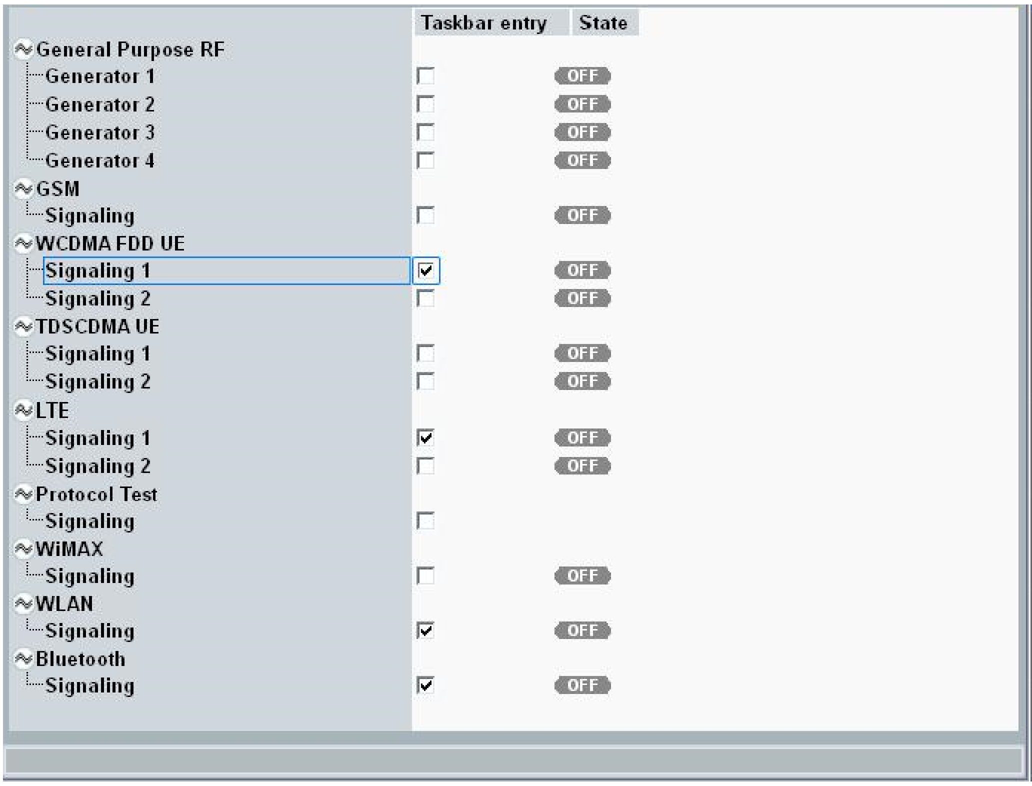


Fig. 3-7: CMW signal standards for car infotainment system testing

3.2 Multi-Standard RF Co-existence Measurement using R&S Instruments

LTE, WLAN and Bluetooth overlapping and adjacent bands are discussed in application note 1MA255 for cellular handsets. Similar scenarios are possible for automotive infotainment units and hence not discussed in this paper. In this application note, some new combinations of standards are highlighted instead.

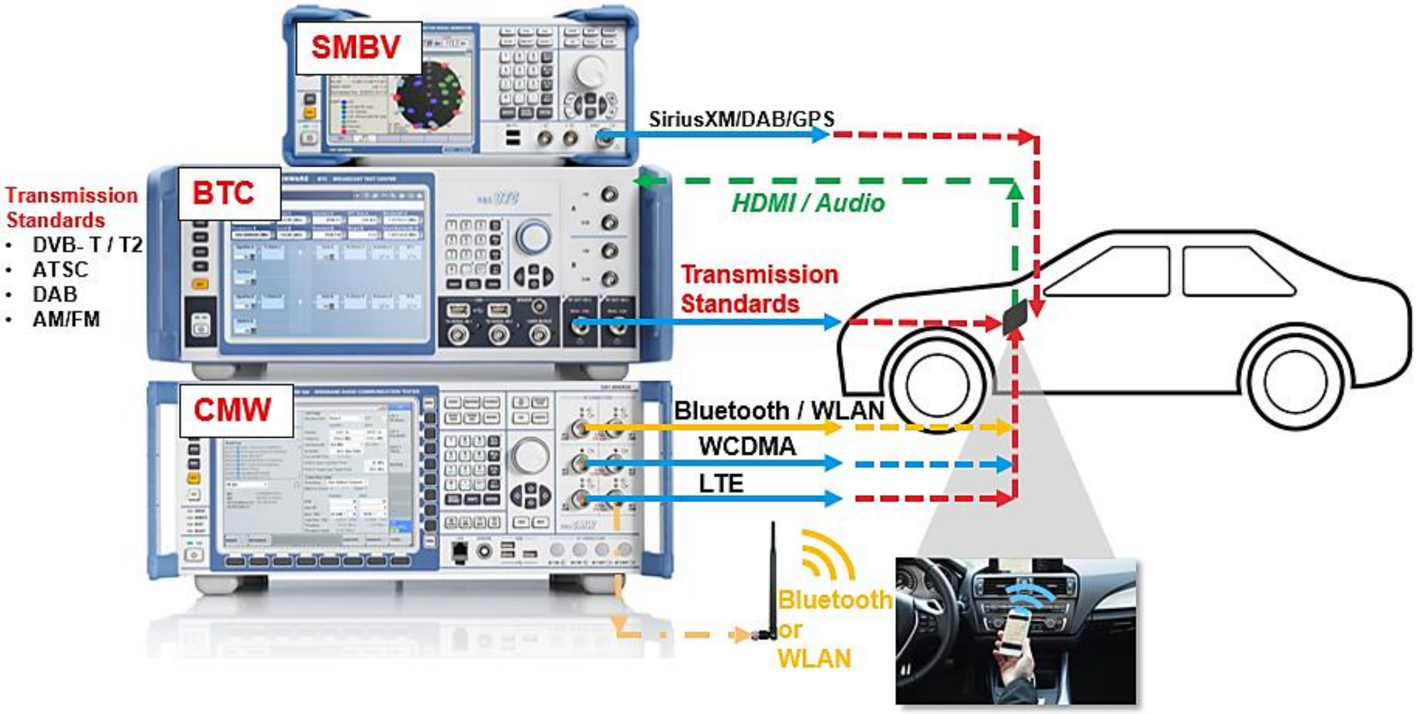


Fig. 3-8: Measurement setup for RF co-existence testing

Fig. 3-8 shows the measurement setup used for characterizing co-existence and adjacent channel leakage problems. In this example, the WCDMA and DVB-T/T2 signal is generated and connected with the DUT as described in sections 3.1.1.1 and 3.1.1.2. The WCDMA network is configured to Band 8 and connected in Test Mode. The DVB-T tuner is tuned to channel 68. The DUT is also paired to an external Bluetooth device (this is optional and may help simulate a more realistic environment).

- After all the instrument connections have been made and the DUT is synchronized to the standards and functioning, switch DVB-T/T2 OFF, i.e. the BTC RF output to OFF.

Fig. 3-9 shows the measurement result in the CMW Multi Evaluation window for the WCDMA UE TX signal with the DVB-T/T2 signal switched OFF. In the test mode, the signal EVM is 2.73% and the DUT receive power level -19.71 dBm.

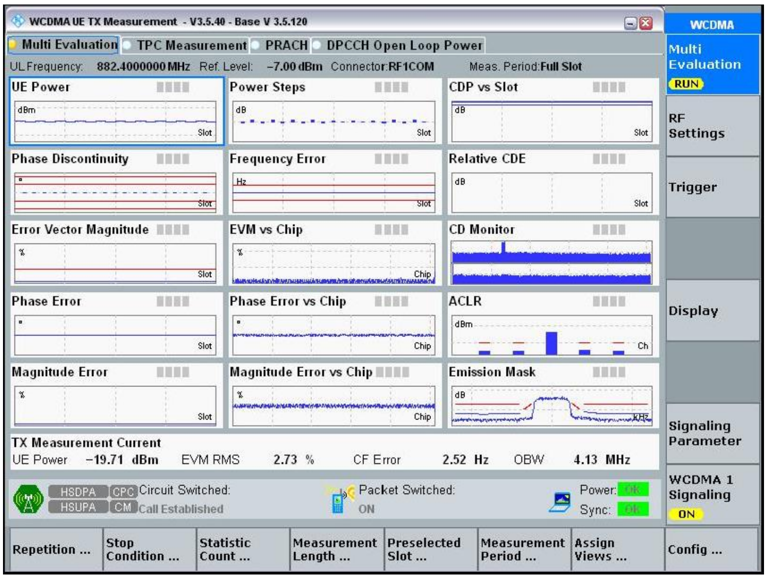
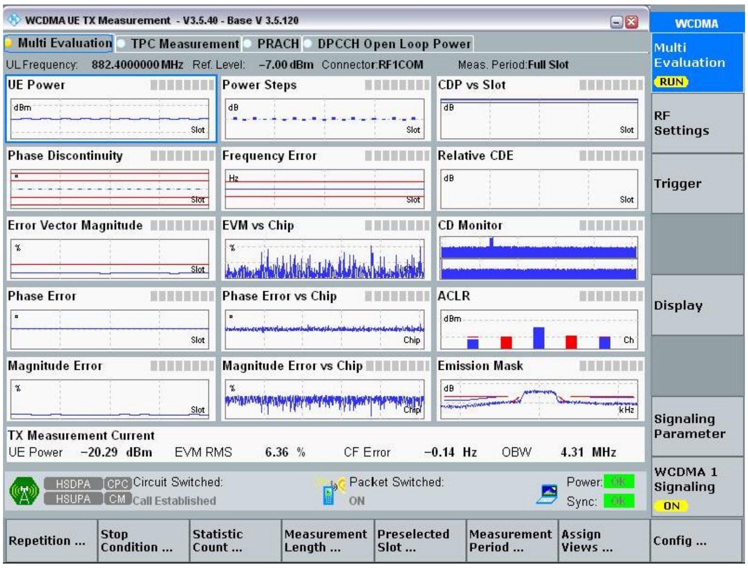


Fig. 3-9: Measurement result of only WCDMA UE TX on the CMW without any DVB-T/T2 signal present

- Switch ON the BTC RF output again to keep conditions similar. After the DVB-T/T2 signal is switched ON the EVM changes to 6.36% and the RX power is -20.29 dBm



The WCDMA signal quality has clearly degraded by the presence of a DVB-T signal. In this example, the DVB-T/T2 signal is centered at 850 MHz with 8 MHz width and the WDMA signal is centered at 882.4 MHz. The problem will even be more apparent if the bands overlap.

Now the same scenario and conditions are repeated and the performance of the DVB-T tuner is observed.

- Connect all the instruments as shown in Fig. 3-8.
- Connect the WCDMA and the DVB-T signal to the DUT.
- Turn CMW WCDMA signaling OFF. Navigate to the Media menu on the DUT, select channel 68 and observe the video.
- Turn CMW WCDMA signaling ON and connect the DUT with voice mode.
- Accept the voice call on the DUT and switch back to the TV channel

Pixel blocking and frame skipping can already be observed on the video

(a) (b) (c)

Fig. 3-10: Performance degradation of the DVB-T tuner in the presence of WCDMA signal

Fig. 3-10 shows the picture quality of the DVB-T receiver before and after the voice call is initiated. Picture (a) shows a clear picture without any frame or pixel blocking. Picture (b) and (c) shows the degradation of the picture quality. Correspondingly, the signal quality of the connection falls (i.e. the EVM degrades from 13.4% to 17.5%) when the power of the DTV signal increases and is shown in Fig. 3-11.

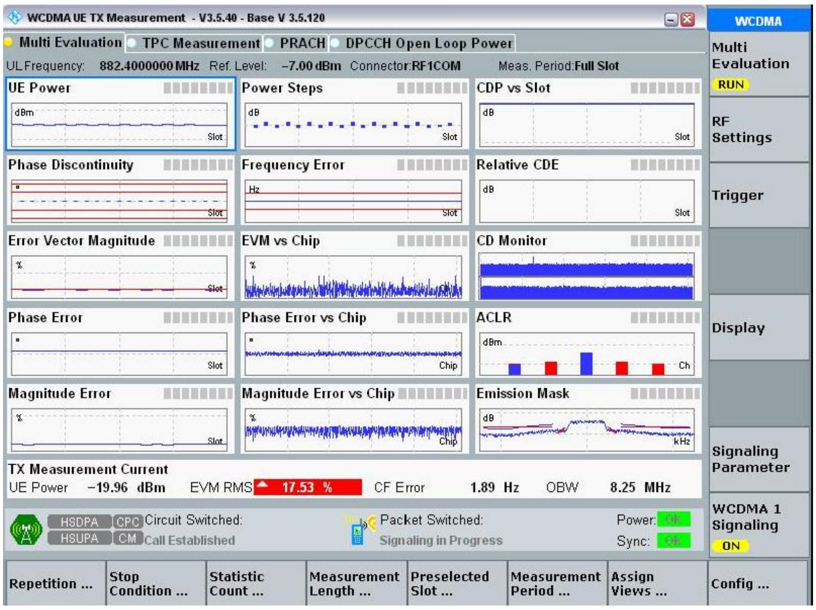


Fig. 3-11: Performance degradation of the call quality as measured on the CMW

3.3 OTA Co-existence and Cross-coupling Measurement

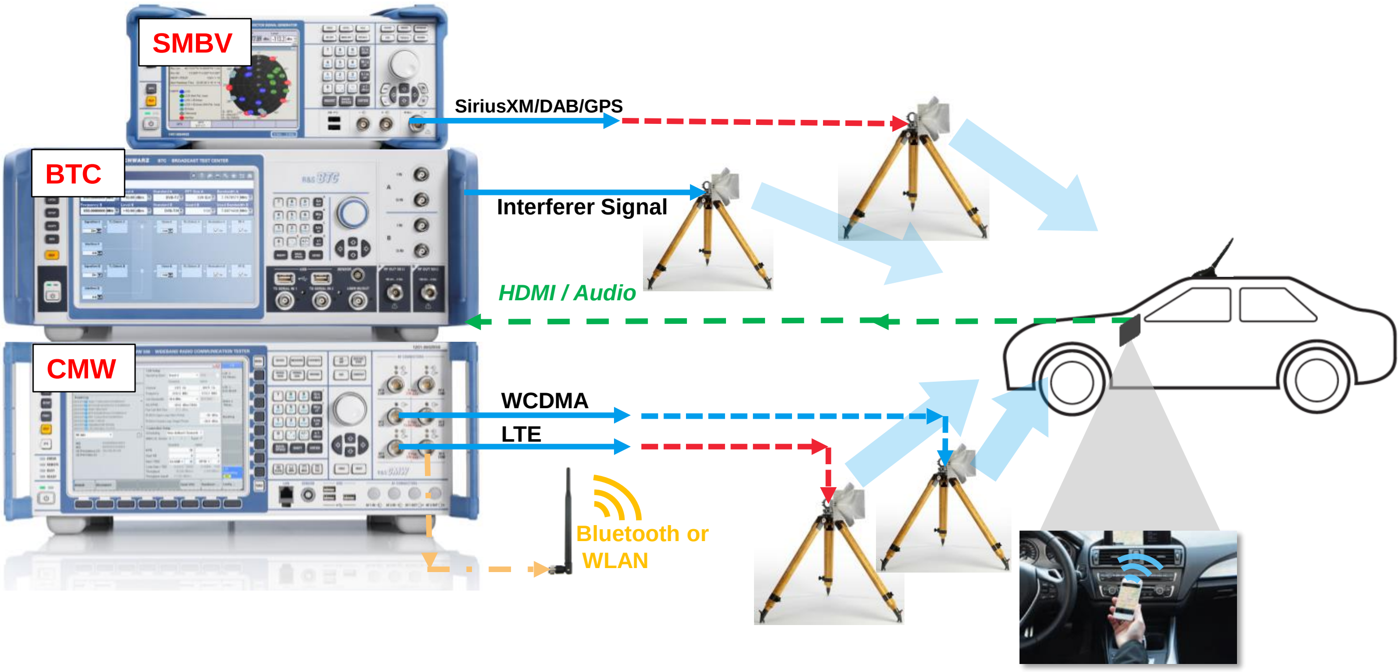


Fig. 3-12: Over the air measurement setup using R&S Equipment and the DUT (the signals represented using blue arrows are active for this example)

Fig. 3-12 shows the test setup required for measuring the co-existence and antenna cross-coupling effect in the DUT. Instead of having a conducted measurement setup, the wired connection to the DUT have all been replaced with Over-The-Air connections. The car infotainment system (DUT) is connected to the antenna(s) mounted to the roof or the A / B / C pillar of the car.

- For this example, the WCDMA signal from the CMW is connected in test mode to the DUT.
  - Select the relevant band on the CMW (For this example Band 1 is selected)

- An interferer signal is transmitted from the BTC.
  - In this case, the LTE signal represents an interferer at 1920 MHz from a mobile device (this could be simulating a rear seat passenger’s own handset placed near the WCDMA antenna in the C-pillar of the car).
  - On the BTC, keep the RF turned OFF until the DUT is registered with the CMW and the test mode connection is established
  - Enter the *Multi Evaluation* window and initialize the measurement. Fig. 3-13 shows the measurement result without interferer signal (EVM = 4.12%, received power level =-29.14 dBm)

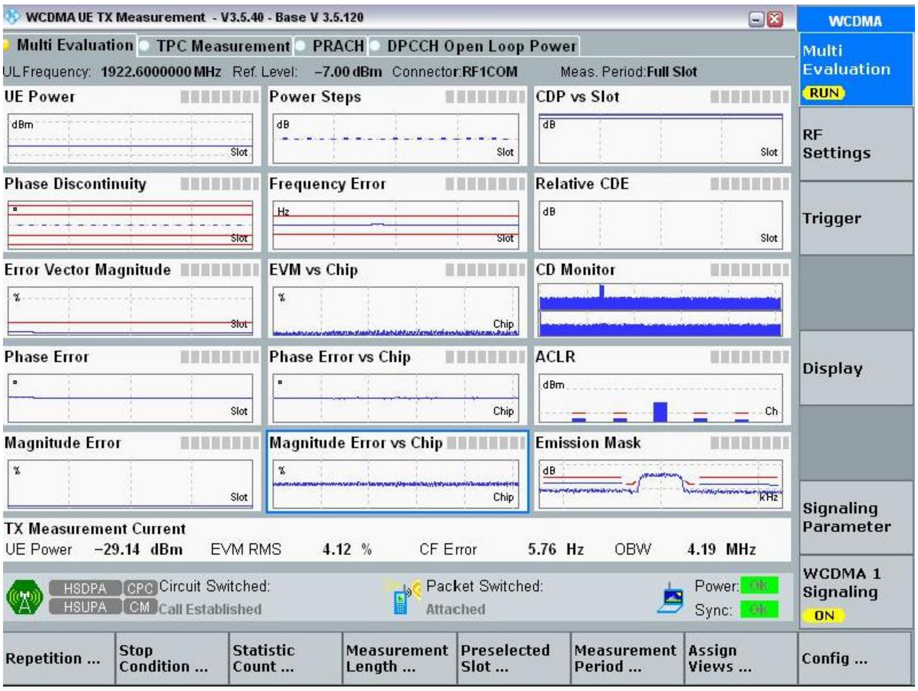


Fig. 3-13: OTA measurement results in Test Mode on the CMW without Interferer

- Switch on the RF signal on the BTC. Fig. 3-14 shows the influence of the service performance of WCDMA on the DUT when LTE interferer from another network provider is introduced. The EVM performance degrades drastically

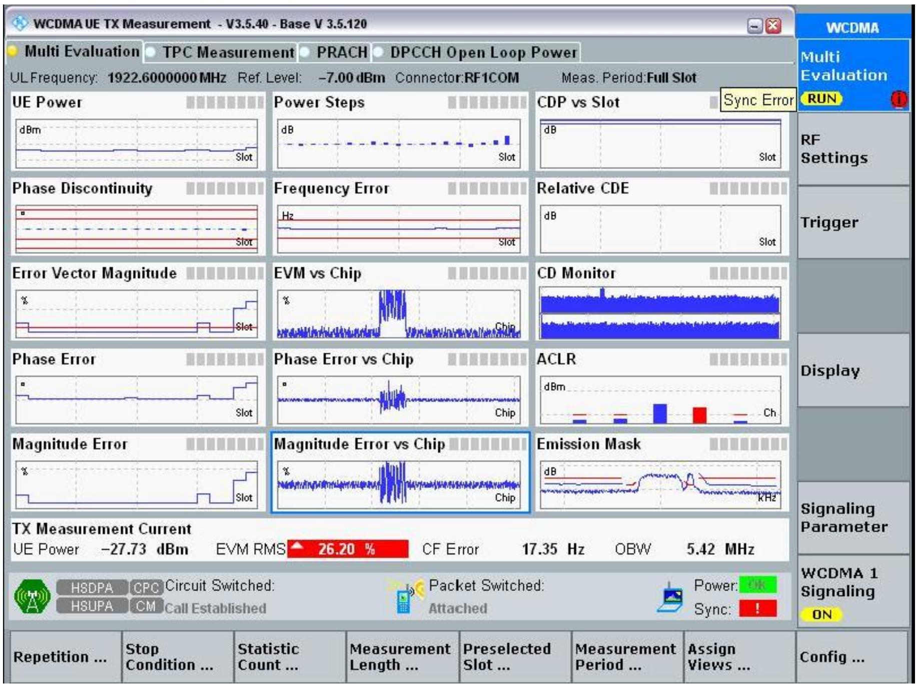


Fig. 3-14: OTA measurement results in Test Mode on the CMW with LTE Interferer

Other additional measurements would be required in the future with the continued evolution of the infotainment system. A scenario, which should be quite common, is a mobile device (simulating driver/passenger's own unit) is placed inside the car and connected via Bluetooth with the DUT (Bluetooth operates in the 2.3 to 2.4 GHz ISM band). An in-device co-existence problem would arise when the DUT would simultaneously transmit a WLAN hotspot signal for in-car use and is connected to a cellular network in an LTE band operating in a neighboring or the same frequency range, or in a band that is harmonically connected to the ISM band, such as between 770 and 800 MHz as overlapping with LTE band13 (also called "USMH-C" when used for 3G) and LTE band 28.

4 References

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3. http://questtel.com/wiki/atsc-channel-center-frequency-table
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9. http://hyperphysics.phy-astr.gsu.edu/hbase/Audio/radio.html
10. https://en.wikipedia.org/wiki/Digital_Radio_Mondiale
11. https://en.wikipedia.org/wiki/Digital_dividend_after_digital_television_transition

5 Ordering Information

Please visit the Rohde & Schwarz product websites at www.rohde-schwarz.com for ordering information on the following Rohde & Schwarz products or contact your local Rohde & Schwarz sales office for further assistance.

- Radio Communication Tester
  - CMW500 wideband radio communication tester
- Broadcast Test Center
  - BTC Broadcast Test Center
- Vector Signal Generator
  - SMBV100A Vector Signal Generator

Rohde & Schwarz

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