RF Testing on Automotive Infotainment Devices Application Note

Products:

- I 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:

Please find the most up-to-date document on our homepage

https://www.rohde-schwarz.com/appnote/1MA275





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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.

			The RF standards that
Troponiosion		DVB-T & DVB-T2	are supported in
Transmission	Video &	ISDB-T	modern automotive
Standarda		DTMB	infotainment device are
Standards	Audia	DAB	shown in the table All
	Audio	Sirius / XM Radio	
		AM/FM	these standards are
		GPS	working over a
	Navigation	GLONASS	frequency range up to 6
	U	Galileo	each other.
		BeiDou	This application note
		WLAN	will aim to introduce the
	Wireless		possible testing
		Pluotooth	methodology of the RF
		Didelocit	standards for
			functionality, co-
		LTE-A	existence and cross-
	Cellular	LTE	coupling
	Ochulai	HSPA	measurements using
		WCDMA (3G)	
		EDGE	Ronde & Schwarz
		GSM (2G)	(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

		AWGN	
Signal Type	Digital TV 🔻	AWGN	Off 💌
Transmission Standard	DVB-T/H 🔻	C/N	20.00 dB 🔽
Frequency Offset	0.000 000 0 MHz 🕶	Settings	
		Bandwidth Coupling	Off 🔻
		Receiver Bandwidth	8.000 000 0 MHz 🔽
		Generated Noise BW	120.000 MHz 👻
			Set Digital I/Q Output
Signal Input Signal Codi	ng TPS Special		

Signal Type: Digital TV and desired Transmission Standard

Next Select : Input signal and configure as shown in the picture below

	••••	in Concrator		
		Non Hierarchical		
Source	\	MM Generator 🔻		
Stuffing		On 💌		
Max. Useful Data	a Rate	27.144 385 Mbit/s		
Useful Data Rate	e	2.505 Mbit/s	DVB-T/H Coding Set	ettings 🗾
			Test TS Packet	Head/184 Payload 🔻
			PID Test Packet	Null 🔻
			PID (Hex)	1FFF
			Payload Test/Stuff	PRBS -
			PRBS	2^23 - 1 🗸
Signal Input S	Signal	Coding TPS Special		

Source: MM Generator

.

тх мм	Gen 1 Player	MMGen 2				
Play File Ru DIVER.TRP 00	nning 00:00:00. :00:06.659	000		(00:00:23.040	Data Rate 5.018 502 Mbit/s
File 🖺		D:\TS	GEN\S	DTV\DVB_25H	z\720_576	ii\LIVE\DIVER.TRP -
Date	04.06.20	014 07:54:02	Size			14 MByte
Orig. Loop Time		23.040 s	Orig.	Data Rate		5.018 502 Mbit/s
Player Output			Seamle	ss Loop		
Data Rate	5.018 502	2 Mbit/s 🔻	Conti	nuity Counter		On 🕶
Packet Length		188	PCR,	DTS/PTS		On 🗸
Nullpacket Stuffing		Off 🕶	TDT/	гот		On -
Stop Data 🔯		None 🗸				
Play Window						
Start	0	0:00:00.000				
Stop	0	0:00:23.040				
Reset Window	_			Pause		Stop
Input Config Player 1	Player 2 Rer	nux Output	Config			

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 RFA

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)

TX Fader A	MMGen	1 Player	MMGen 2	2				
Frequency A		Level A	S	standard /	A FI	FT Size A	Used Ba	andwidth A
850.000 000	000 MHz 👻	0.00 d	Bm 🔻	DVB-	T2 -	32	<▼ 7.60	7 142 9 MHz
Frequency B		Level B	s	Signal Typ	e B			
2 400.000 000	000 MHz 👻	8.00 d	Bm 💌	AF	RB 🕶			
Fading	On - Co	onfiguration	n 🛛 🖓	Sta	andard/	Fine Delay 🕶	🔇 Se	t to Default
Standard	User -							Equal
				Cop	y Path	Group 1	To 2	🚺 Сору
	1 - 1 _{Fine}	1 - 2 _{Fine}	1 - 3 _{Fine}	1 - 4 s	tandard	1 - 5 _{Standard}	2 - 1 _{Fine}	2 - 2 Fine
State	On	Off	Off		Off	Off	Off	Off
Profile	Pure Doppler 💌	Rayleigh 📘	 Rayleigh 	🔹 Ray	leigh 💌	Rayleigh 💌	Pure Doppler 💌	Rayleigh
Path Loss /dB	0.00	0.0	00	0.00	0.00	0.00	3.00	
Basic Delay /µs	0.000 000 0	0.000 000	0 0.00	0 000 0	0.000 000 0	0.000 000 0	0.000 000 0	0.000 0
Additional Delay /µs	0.000 000 0	0.000 000	0 0.00	0 000 0	0.000 000 0	0.000 000 0	28.000 000 0	0.000 0
Resulting Delay /µs	0.000 000 0	0.000 000	0 0.00	0 000 0	0.000 000 0	0.000 000 0	28.000 000 0	0.000 0
Power Ratio /dB	0.00	0.0	00	0.00	0.00	0.00	0.00	
Frequency Spread	0.100 0	0.100	0	0.100 0	0.100 0	0.100 0	0.100 0	0.1
Const Phase /Dea	0.0	0.	.0	0.0	0.0	0.0	0.0	
Speed km/h 💌	220.000	0.00	00	0.000	0.000	0.000	2.880	0.
Freq. Ratio	-1.00	1.0	00	1.00	1.00	1.00	1.00	T
0								Þ
Fading/Baseba	nd Config.	Profile Se	ttings E	xternal R	F			

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 G	enerator						
Generator	1	2	3	4	5	6	7
State	On 🔫	On 🕶	On 🔫	On 👻	On 🔻	On 🔫	
Usage	Interferer	Interferer	Interferer	Interferer	Interferer	Interferer	Inter
Waveform[.wv]	FM_SMAL_75KHZ	HD_FMr208c	DRM12dBFS	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
0							Þ

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

Senerator/Signaling Controller	-		- 🔊 🔯	Gen Ctrl
	Taskbar e	ntry State		
∼ General Purpose RF				
-Generator 1		OFF		
-Generator 2		OFF		
Generator 3		OFF		
Generator 4		OFF		
≈ GSM				
Signaling		THE		
∼WCDMA FDD UE				
Signaling 1		OFF		
Signaling 2		OFF		
~ TDSCDMA UE				
-Signaling 1		OFF		
Signaling 2		OFF		
∾LTE				
Signaling 1	1	OFF		
-Signaling 2		OFF		
~ Protocol Test				
L-Signaling				
~WIMAX				
		OFF		
≈WLAN				
L-Signaling	1	OFF		
~ Bluetooth				
L-Signaling	v	OFF		
				Config

Next enter the WCDMA FDD UE Signaling 1 Menu

5 WCDMA UE Signaling 1 - V3.5.40 - Base V 3.5.120	_			WCDMA
Connection Status Cell HSDPA CPC HSUPA CM Circuit Switched Registered Packet Switched Attached	Cell Setup Band Channel Frequency Output Power	Band 8 Downlink 2937 Ch 927.4 MHz -56.00 dBm	Uplink 2712 Ch 882.4 MHz	WCDMA 1 TX Meas WCDM 5 RX Meas
CMW Demod. Info Power: Sync: Event Log 16:00:02 @RRC Connection Released	Total Output Scrambling Code P-CPICH	-56.00 dBm 0 hex -3.3 dB	0 hex Code 0	Go to
16:00:01 CS Radiobearer Released 16:00:00 Test Loop Openend 15:59:59 OUE Terminated Call Release 15:57:01 CS Call Established 15:57:01 Test Loop Closed	Connection Setup UE term. Connect Type RMC Domain	Test Mode ▼ Voice Video SRB only	3	Routing
UTRA FDD (Current Cell) Lower Upper CPICH RSCP [dBm]	Data Rate Loop Mode 2 Sym. UL CRC DL Resource in Us	DL 12.2 kbps V Loop mode 2	L 12.2 kbps •	Signaling Parameter
Pathloss (dB)	Data Pattern	PRBS9	. 2	WCDMA-UE Signaling ON
Unregister Connect Test Mode		Send SMS		Config

- 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%.

🍪 WCDMA UE TX	(Measurement -	V3.5.40 - Base V 3	3.5.120				- 2	WCDMA
Multi Evaluat JL Frequency:	ion 💿 TPC Mea 882.4000000 MHz	surement P Ref. Level:7	RACH DPCCH	Open Loop pr:RF1COM	Power Me	as. Period:Full S	lot	Multi Evaluation
UE Power		Power	Steps	1	CDP V	rs Slot		RUN
dØm		Slot d9	•	Slot	дв		Slot	RF Settings
Phase Disconti	inuity 🔳	Freque	icy Error		Relati	ive CDE	1	
•		Hz		SIGE	dB		Slot	Trigger
Error Vector Ma	agnitude 🔳	EVM vs	Chip		CD M	onitor		10
1		Slot I		Chip				
Phase Error		Phase E	rror vs Chip	1	ACLR		1	Dicolau
•		-			dBm			Display
		Slot		Chip			Ch	2
Magnitude Erro	or II	Magnitu	ide Error vs Chip	U.	Emiss	ion Mask	1	
×		X			dB		N	
TX Measureme	ant Current 🦽	Slot		Chip	P-u-alian (pr	and a second second	Low KHE	Signaling Parameter
UE Power -1	9.40 dBm E	VM RMS	2.70 % CF 8	Error	1.90 H	z OBW	4.14 MHz	
HSDPA HSUPA	CPC Circuit Sw CM Call Estate	vitcheu. lished	Par Atta	cket Switch ached	ed:	<u></u>	Power: 08	WCDMA 1 Signaling
Repetition	Stop Condition	Statistic Count	Measurement Length	Preselec	ted	Measurement Period	Assign Views	Config

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.

	Taskbar entry	State
🗞 General Purpose RF		
-Generator 1		OFF
-Generator 2		OFF
Generator 3		OFF
Generator 4		OFF
≪ GSM		
Signaling		OFF
∞WCDMA FDD UE		
Signaling 1		OFF
Signaling 2		OFF
≈TDSCDMA UE		
-Signaling 1		OFF
Signaling 2		OFF
∾LTE		
-Signaling 1	v	OFF
Signaling 2	Г	OFF
≫Protocol Test		
^L Signaling		
≪WIMAX		
Signaling		OFF
∾WLAN		
LSignaling	V	OFF
≫Bluetooth		
Signaling	V	OFF



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.

🚸 WCDMA UE TX Measurement - V3.5.	40 - Base V 3.5	.120			8	WCDMA
Multi Evaluation TPC Measurement PRACH DPCCH Open Loop Power						Multi
UE Power	Power Ste	eps	C	DP vs Slot		RUN
d Bm Slot	dB		Slot	18	Slot	RF Settings
Phase Discontinuity	Frequency	y Error 🛛	R	elative CDE		
*	Hz		Slot	98	Slot	Trigger
Error Vector Magnitude	EVM vs Cl	nip 🔳		D Monitor	建建装置	-
%	N		Chip			
Phase Error Vs Chip				CLR	Diculay	
Slot			Chip	dBm	<u> </u>	Dispidy
Magnitude Error vs Chip				mission Mask		
%Slot	X	840 mm / 897 800 900 900 900 900 900 900 900 900 900	Chip	1B	C	Signaling
TX Measurement Current UE Power −19.71 dBm EVM	RMS 2.7	'3 % CFE	rror 2.	52 Hz OBW	4.13 MHz	Parameter
HSDPA GPC Circuit Switched: Packet Switched: Power Control						WCDMA 1 Signaling ON
Repetition Stop Condition St	atistic unt	Measurement Length	Preselecter Slot	d Measurement Period	Assign Views	Config

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

🚸 WCDMA UE TX Measurement - V3.5.40 - Base V 3.5.120 🔤 🔯						
Multi Evaluation TPC Measurement PRACH DPCCH Open Loop Power						
UL Frequency: 882.4000000 MHz Re	Level: -7.00 dBm Connec	tor:RF1COM M	eas. Period:Full S	lot	Evaluation	
UE Power	Power Steps	CDP	vs Slot		RUN	
dBmSlot	dB	Slot		Slot	RF Settings	
Phase Discontinuity	Frequency Error	Relat	tive CDE			
*	Hz	Slot		Slot	Trigger	
Error Vector Magnitude	EVM vs Chip	CD M	onitor			
X Slot						
Phase Error	Phase Error vs Chip	Dicalau				
• Slot	Variopene generalistic anti-feriosistic articles and	dBm Chip		Ch		
Magnitude Error	Magnitude Error vs Chip	Emis	sion Mask			
3	1	dB	and Version and			
	anananjanan disinta disi			kH2	Signaling Parameter	
UE Power −20.29 dBm EVM I	RMS 6.36 % CF	Error -0.14 H	Iz OBW	4.31 MHz		
HSDPA CPC Circuit Switch HSUPA CM Call Establishe	ed: d International Participation Participation Participation Participation Participation Participation Participation	icket Switched: I	<u></u>	Power: OK Sync: Ok	Signaling	
Repetition Stop Condition Sto	atistic Measuremen unt Length	t Preselected Slot	Measurement Period	Assign Views	Config	

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



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.

🚸 WCDMA UE TX Measurement - V3.5.40 - Base V 3.5.120 📃 🔯								
Multi Evaluation 💿 TPC Measure	ment 💿 PRACH 💿 DPCCH O	pen Loop Pow	er		Multi			
IL Frequency: 882.4000000 MHz Ref. Level: -7.00 dBm Connector:RF1COM Meas. Period:Full Slot								
UE Power	Power Steps	CDP	vs Slot		RUN			
d Bm Slot	dB	Slot		Slot	RF Settings			
Phase Discontinuity	Frequency Error	Rela	ntive CDE					
• Stor	Hz	Slot dB		Slot	Trigger			
Fror Vector Magnitude	EVM vs Chip	CD I	Monitor					
X Slot	x Marched at print will fill by definition of the	uniterilurestyle	11					
Phase Error	Phase Error vs Chip	ACL	R		CALL ST.			
• Slot	Siot							
Aagnitude Error	Magnitude Error vs Chip	Emi	ssion Mask	TRADES.				
*		dB						
Slot	Indiana stratan (1998) Barrashi Sarata	Chip		kHz	Signaling Parameter			
JE Power − 19.96 dBm EVM F	RMS 🔶 17.53 % CFE	rror 1.89	Hz OBW	8.25 MHz				
HSDPA CPC Circuit Switche HSUPA CM Call Establishe	d Sign	ket Switched aling in Progress		Power: 000 Sync: 000	WCDMA 1 Signaling			
Repetition Stop Sta Condition Co	tistic Measurement	Preselected Slot	Measurement Period	Assign Views	Config			

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)

🊸 WCDMA UE TX Measurement - V3.5.40 -	Base V 3.5.120				WCDMA	
Multi Evaluation 🔿 TPC Measurement 🔍 PRACH 🔿 DPCCH Open Loop Power						
UL Frequency: 1922.6000000 MHz Ref. Level: -7.00 dBm Connector:RF1COM Meas. Period:Full Slot						
UE Power F	ower Steps	CDP	vs Slot		RUN	
dBmSlot	dB	 Slot		Slot	RF Settings	
Phase Discontinuity	requency Error 🛛 🔳	Rela	tive CDE			
* _	Hz	Slot dB		Slot	Trigger	
Error Vector Magnitude	WM vs Chip 🔳	CD M	lonitor			
3tur	X	Chip				
Phase Error ACLR Phase Error vs Chip						
•	•	dBm			Dispidy	
Slot		Chip		Ch		
Magnitude Error	Aagnitude Error vs Chip	Enis	sion Mask	NARABARI I		
x	Land and the second	dB	- (maining	<u> </u>	-	
Slot Chip						
TX Measurement Current UE Power -29.14 dBm EVM RMS	3 4.12 % CFE	rror 5.76 I	Hz OBW	4.19 MHz	Parameter	
HSDPA CPC Circuit Switched: Power: Circuit Switched: Power: Circuit Switched: Power: Circuit Switched: Sync: Circuit Switched Sync: Circuit Switched						
Repetition Stop Condition Statis	tic Measurement Length	Preselected Slot	Measurement Period	Assign Views	Config	

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

🤣 WCDMA UE TX	(Measurement -)	V3.5.40 - Base V	3.5.120				WCDMA
Multi Evaluation TPC Measurement PRACH DPCCH Open Loop Power ULFrequency: 1922.6000000MHz Ref. Level: -7.00 dBm Connector:RF1COM Meas. Period:Full Slot						Multi Evaluation	
UE Power	11 12 12 13	Power S	Steps I		CDP vs Slot	Sync Error	(RUN)
dBm	· · · · · · · · · · · · · · · · · · ·	Slot dB		Slot	dB	Slot	RF Settings
Phase Disconti	inuity	Freque	псу Еггог	F	Relative CDE		
				Slot	dB	Slot	Trigger
Error Vector M	agnitude	EVM vs	Chip		CD Monitor		
*		Slot WANHING	Latin Latin	www.hershill	and a second		
Phase Error	hase Error Phase Error vs Chip ACLR						
-		Slot		Chip	dBm	Ch	Dispidy
Magnitude Erro	or IIIII	Magnitu	Ide Error vs Chip		Emission Mask		
		Slot	reigen states see the party mailtains	Chip	dB	A THE	Signaling
TX Measureme	ent Current 27.73 dBm = F		5.20 % CE F	rror 17	35 Hz OBW	5.42 MHz	Parameter
HSDPA HSUPA	CPC Circuit Sv CM Call Estab	vitched: lished	Pac Atta	ket Switched ched		Power: 2016 Sync: 1	WCDMA 1 Signaling ON
Repetition	Stop Condition	Statistic Count	Measurement Length	Preselecte Slot	d Measuremen Period	t Assign Views	Config

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.

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