DAB High-Quality Signal Capture and Near-Lossless Scenario Reproduction

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1. Introduction

For testing the DAB reception capability of vehicle head units, in addition to using the professional instrument RWC2010C for verifying signal parameters and protocol conformity, there is also a need for actual scenario simulation tests. The latter essentially requires collecting and storing real-world signals from overseas and reproducing the scenarios in the laboratory.

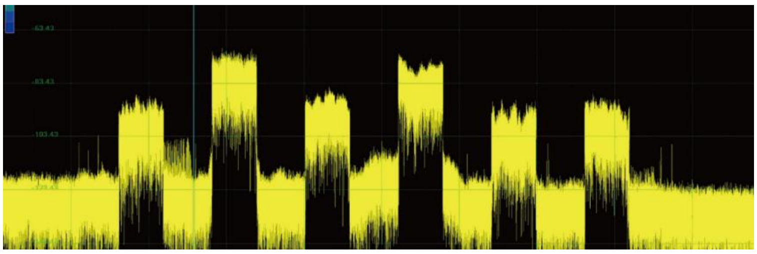
Generally, a radio frequency recording and playback system is used to capture, store, and replay RF scenes, but how should the capture equipment be selected? How do we choose a reliable antenna to pair with capture and playback? How can we restore the on-site RF scene with as little distortion as possible? All of these require careful consideration.

The main content of this paper is a preliminary discussion of the above core issues.

2. High-Precision Capture

Only with high-precision capture capability is high-precision playback possible. So how can an RF capture and playback system ensure high-precision capture?

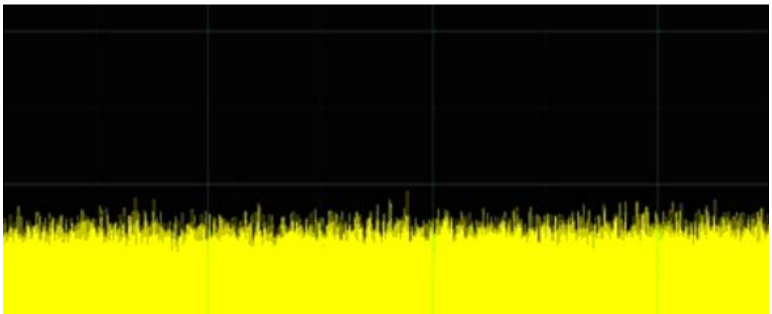
For a broadband RF signal as shown in the figure below, how do we carry out high-precision capture? We need to optimize in several aspects.



A schematic of an actual RF scenario

2.1 Background Noise

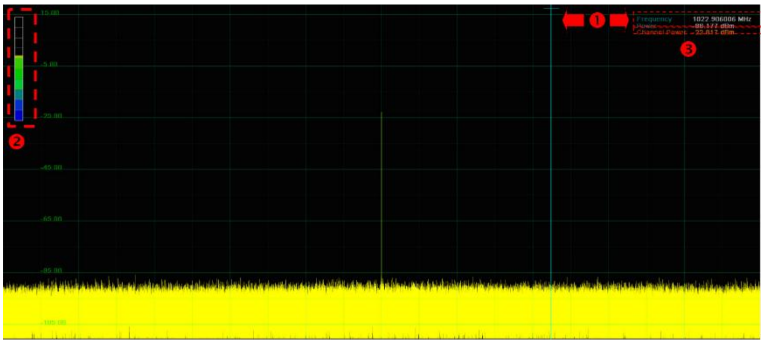
The first important optimization is background noise. Because background noise determines the device’s ability to capture low-power signals. For example, to capture weak signals such as GPS, it is absolutely impossible if the background noise is not good enough.



Background Noise

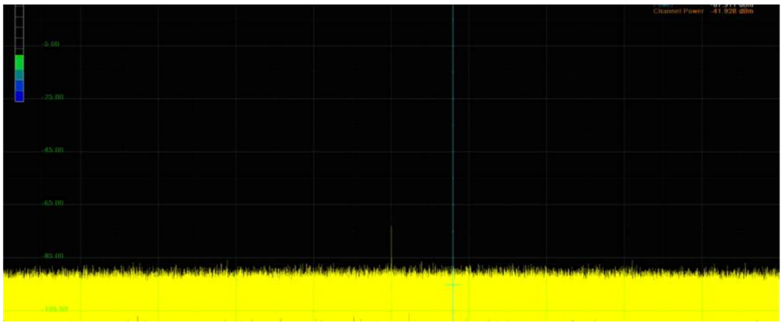
2.2 Carrier Suppression Capability

If a direct sampling scheme is used, carrier leakage will inevitably be introduced, as shown in the figure below:



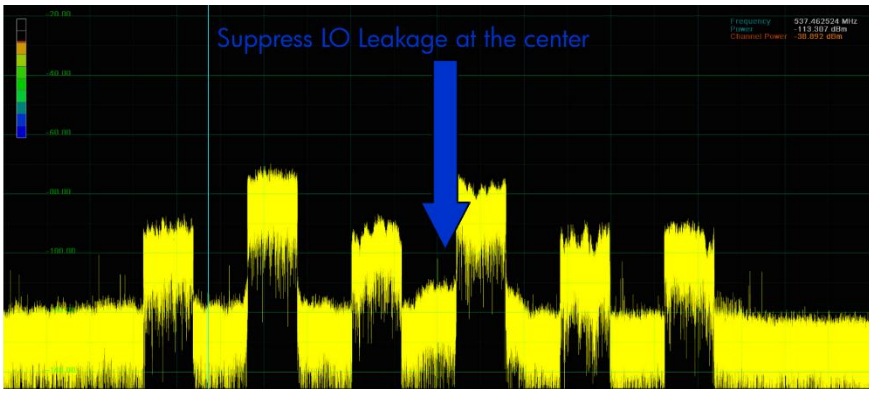
Instrument LO Carrier Leakage

After optimization, the following result can be obtained:



Optimized LO Leakage

Therefore, whether the RF capture and playback system has self-optimization capability is very important. At the same time, to further reduce the impact of LO leakage on the captured signal, the capture parameter settings should try to offset the instrument's LO frequency from the real RF signal, as shown in the figure below:



Optimized capture settings

Through optimization, the impact of the instrument on the captured signal can be minimized, thus ensuring capture accuracy.

2.3 High Sampling Rate and Bit Depth

Returning to the essence of RF capture, it is to perform high data-rate IQ analysis and storage of RF signals. Therefore, the sampling rate and bit depth determine the accuracy of the captured signal. The typical parameters of RFCS are shown in the table below:

ADC Fs (MHz)	BW (MHZ)	I/Q rate (Mega Samples per Second, MSPS)	Throughput (MB/s)
MP7600 RF-down-converter path (I/Q sampling)			
250	100	125	500
250	54	62.5	250
250	25	31.25	125
250	12.5	15.625	62.5
250	8.33	10.41	41.66
250	4	5.2	20.83

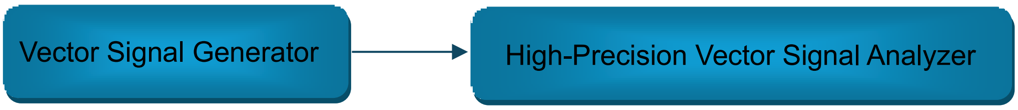
However, it should be noted that high sampling rates and bit depths will cause data throughput to increase rapidly, thus posing challenges to the instrument's design architecture and high-speed transmission capability, and may even affect the instrument's operational stability. This is also an important aspect in evaluating RF capture and playback systems.

3. Near-Lossless Playback and Verification

First, we discuss how to verify whether the playback signal has significant distortion. To solve this problem, it is necessary to use a standard signal source for comparative testing.

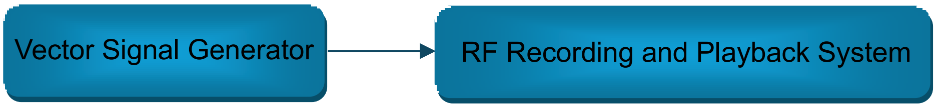
The first step of verification is to use a high-precision vector signal analyzer with C/N simulation function to perform EVM or MER verification on the signal generated by the standard vector signal generator. If the vector signal generator is a modulation signal of a specific standard such as DVB-C or others, it is best for the vector signal analyzer to support the corresponding standard.

The test block diagram is as follows:

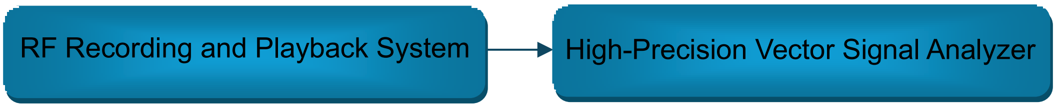


The core metric for testing is EVM or MER because this value comprehensively reflects the quality of the signal. For calibrated comparison, it is necessary to set a specific bandwidth of AWGN to simulate C/N, thereby precisely simulating EVM or MER. If the vector signal generator also has IQ distortion simulation, it provides greater flexibility in verification.

The second step of verification is to use the RF recording and playback system to capture and store the signal from the vector signal generator (keeping the same parameter settings).



The third step of verification is to use the RF recording and playback system to play back the captured signal and then use the high-precision vector signal analyzer again to obtain the EVM or MER.



The difference between the two obtained EVM or MER values is the degree of distortion. Generally, if a deviation of 0.5–1 dB can be achieved, it can be considered almost distortion-free. The RFCS system can achieve such capture and playback capability.

It is particularly important to note that playback precision determines the ability to reproduce scenarios in the future. Although the RF capture and playback system is not all there is to scenario reproduction, it is the foundation for ensuring near-lossless scenario reproduction.

4. Scenario Reproduction

This paper has analyzed high-precision capture and near-lossless playback and has expressed that these are not sufficient conditions for near-lossless scenario reproduction. So what other factors will affect the accuracy of scenario reproduction? And what methods can we use to try to avoid these problems?

We can use a table to briefly define the factors that need to be considered for near-lossless restoration of DAB (or other broadcast signals) received by the head unit, and also propose simple solutions.

Parameter	Influencing Factors	Solutions	Remarks
Directional Characteristics	The vehicle antenna has a directional pattern; its reception ability changes with orientation.	Fix the orientation of all test vehicles to ensure consistency as much as possible.	The radiation pattern determines the directional characteristics of the received signal.
Field Strength	The magnitude of the airborne signal field strength at the antenna receiving location, antenna gain, and receiver antenna loss.	Use spatial field strength detection methods to ensure that the field strength at the antenna receiving point matches the field strength during capture.	This power requires the playback equipment to have the ability to adjust the power. This part is key to why complete lossless reproduction is impossible, because considering directionality during capture will greatly reduce capture efficiency.

Consistency	When the playback system plays back the signal, it differs from the real signal.	Use a high-precision RF capture and playback system to ensure playback accuracy, including accuracy over time.	From the system perspective, power adjustment should not change the signal characteristics.

After considering these factors, the possible solutions are:

1、 Use a fixed shielded space to simulate scenario reproduction;

2、 Fix the antenna position: use a loop antenna to handle the 9 kHz–30 MHz band, and a biconical antenna to handle the 30 MHz–300 MHz band. The antenna position should avoid being extremely close to the vehicle's antenna to reduce directional effects as much as possible, but power adjustment possibilities must also be considered.

3、 Keep the parking position of the vehicle in a fixed orientation.

5. Typical Testing Tools

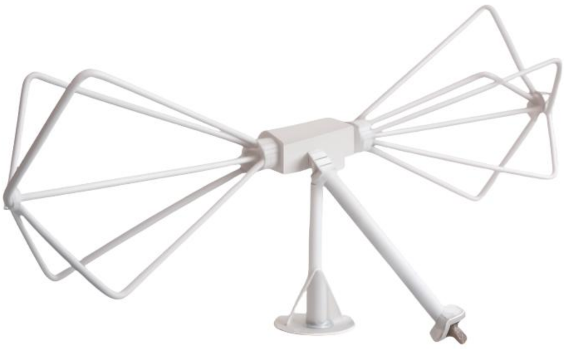
The key tools for achieving high-quality DAB signal capture and near-lossless scenario reproduction include:

1、 The RF capture and playback system RFCS

- Recording bandwidth can be set arbitrarily from 2M to 100 MHz
- Frequency range covers 300 kHz to 6.0 GHz
- IQ data rate 500 MBps
- 250 MS/s sampling rate, 16-bit ADC precision
- 1PPS, IRIG-B support (requires additional option)
- Supports maximum hold, minimum hold, and average processing display
- More than 20 marker functions to meet various marker testing needs
- Data format compatible with MATLAB; provides IQ data processing software tools.

2、 Antennas PLA0930/PDA30300

9K-30MHz Antenna



30M-300MHz Antenna

6. Conclusion

Achieving near-lossless DAB RF real-scene reproduction to test the DAB reception capability of vehicle head units has great reference value. Although it cannot completely replace rigorous laboratory functional and performance tests, it can serve as a good auxiliary verification. This article discusses some basic principles of RF capture and playback and key factors for achieving high-precision capture and playback, and discusses the factors that need to be considered for scenario reproduction. Given my limited knowledge, I welcome your corrections. Please feel free to call us for communication at 010-64327909.