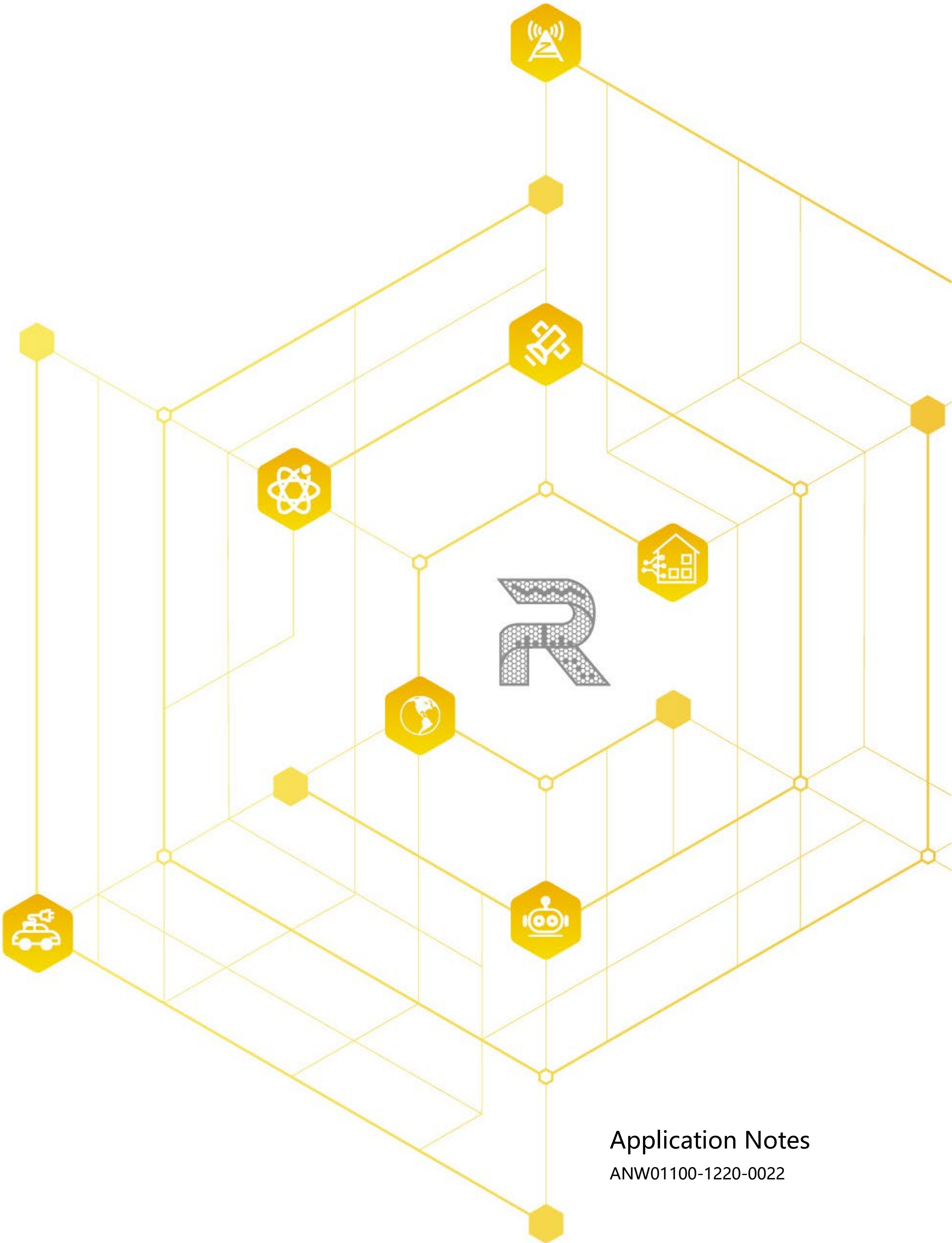
Test Solution for FM Stereo Receivers



Application Notes

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Introduction

FM stereo broadcasting refers to transmitting audio with a sense of spatiality. Stereo technology in audio refers to reproduced sound characterized by spatial distribution, such as sense of direction and layering, which requires multiple audio sources played from different positions to create depth. FM stereo broadcasting has been developed since the 1960s and, despite its long history, it is still widely used in modern automobiles as a standard feature in mobile audio systems. This article will provide technical descriptions and RIGOL's recommended solutions to test FM stereo receivers from the perspectives of FM broadcasting as well as FM stereo application in automotive electronics.

FM and FM History

All forms of communication broadcasting use electromagnetic waves to transmit information, using the electromagnetic wave as a carrier. Information is loaded onto the carrier in various ways for transmission, and then extracted at the receiver. The former process is called modulation, while the latter process is demodulation.
Based on the type of modulation signal, modulation can be divided into analog and digital modulation. Frequency modulation (FM) is a type of analog modulation.
FM (frequency modulation) is a modulation method where the frequency of the modulated signal (carrier frequency, e.g., 107.5MHz broadcast carrier) is controlled by the signal waveform to be transmitted (e.g., the original audio signal for FM broadcasting). It is a type of analog modulation. Similar methods include Amplitude Modulation (AM), Phase Modulation (PM), etc.

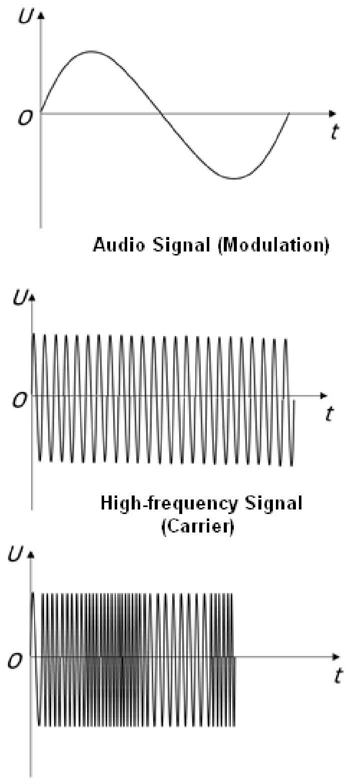

Figure 1. FM Modulation Signal, Modulated Signal, and Modulation Result

FM has gone through multiple stages in the history of radio broadcasting:

- In 1935, American labs proved that FM could be used for broadcasting, which initiated its development.
- In 1941, the US began FM broadcasts in the 43 MHz–50 MHz range, and later shifted to 88 MHz–108 MHz.
- In 1958, dual-channel FM stereo broadcasting began. In 1961, the US Federal Communications Commission (FCC) decided to adopt the AM-FM system (i.e., pilot-tone system) as the standard for FM stereo broadcasting, leading to its development worldwide.
- Subsequently, the former Soviet Union began using FM stereo broadcasting in 1959, followed by Japan in 1962 and West Germany in 1963. China's FM stereo broadcasting started in Harbin in 1979 and became widespread nationwide in the mid-1980s.

Figure 2 Scene of Early Use of Radio Receivers

After its invention, radio broadcasting quickly grew in other industries such as automotive.

- In 1930, the Galvin Manufacturing Corporation in the US first offered car radio installations under the Motorola brand.
- In 1933, Crossley (UK) launched the first mass-produced car equipped with a radio.
- In 1952, Blaupunkt (Germany) introduced an FM car radio, marking the start of in-car stereo audio.
- In 1955, Chrysler offered the first optional all-transistor car radio, ushering in the semiconductor era for car radios.

Figure 3. FM Radio Broadcasting in Automobiles

FM and FM History (Stereo part)

Stereo refers to sound with three-dimensional quality. In audio technology, it signifies reproduced sound possessing spatial characteristics like directional perception and depth. This requires multiple audio channels played from different directions to create a layered effect.

In broadcasting, stereo means the original audio is divided into left (L) and right (R) channels, and FM stereo broadcasting must transmit both channels simultaneously while remaining compatible with mono FM receivers.

To achieve compatibility, FM stereo broadcasting retains the signal portion transmitted during monophonic broadcasting. The “sum” signal of the left and right channels (L+R) is transmitted in the baseband range of 30 Hz-15 kHz, known as the main channel. Building upon the main channel, the “difference” signal (L-R) is modulated onto a 38kHz subcarrier using the shift of spectrum. After the signal is demodulated at the receiver, the main channel and subchannel are recovered. The subchannel is demodulated to recover the “difference” signal, which is then combined with the “sum” signal through addition and subtraction matrixing to finally restore the original left and right channel signals.

Spectrum shifting of the subchannel creates a subcarrier. Depending on the modulation method, FM stereo broadcasting varies:

- FM-FM system: the L-R difference signal frequency-modulates the 38 kHz subcarrier via frequency modulation (polar modulation), mainly used in the former Soviet Union and Eastern Europe.
- AM-FM system: the L-R difference signal amplitude-modulates the 38kHz subcarrier (pilot-tone system), used in Europe, America, Japan, China, and most countries.

In the pilot-tone system, the “sum” (L+R) is labeled M, the “difference” (L-R) is S, and the pilot signal amplitude is P. The complete baseband composite signal for FM stereo can be expressed as follows:

$$u_t = M + S \sin \omega_s t + P \sin\left(\frac{\omega_S}{2}\right) t$$

ω _S: subcarrier frequency (38 kHz)
M: L+R
S: L-R
P sin(ωS/2)t: pilot signal (19 kHz)

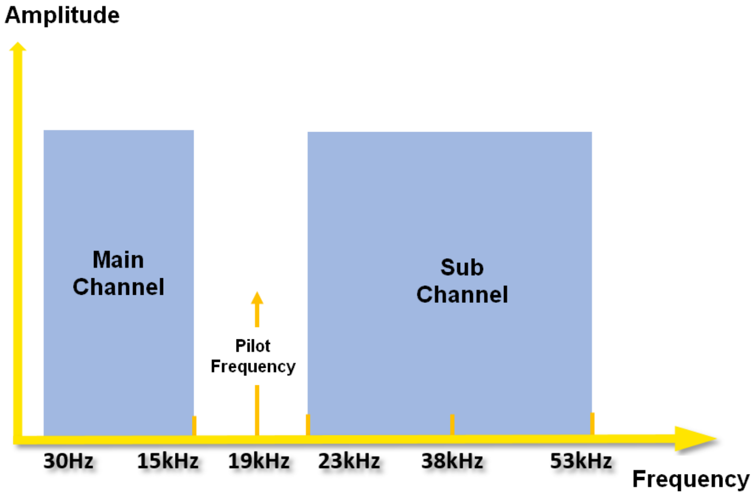

Figure 4 Baseband Spectrum of the Pilot-System

FM and FM History (Testing Part)

FM stereo receiver testing cannot be done with conventional FM signals, and a dedicated FM stereo signal generator is required. According to the national standard (recommendation) GB/T 6163-2011 “Measurement Methods for FM Broadcast Receivers”, the following instruments are required to generate analog FM stereo signals for receiver testing:

- Audio signal generator: frequency range at least 30 Hz to 15 kHz, harmonic distortion < 0.3%
- Stereo signal generator: modulation methods M, L, R, S, single tone, pilot; separation > 55 dB (100 Hz-4 kHz), > 40 dB (30 Hz-15 kHz)
- RF/FM signal generator: frequency range no less than 85 MHz-110 MHz, ideally in 38 MHz-250 MHz; FM deviation range 0 kHz-75 kHz; supports internal and external modulation sources

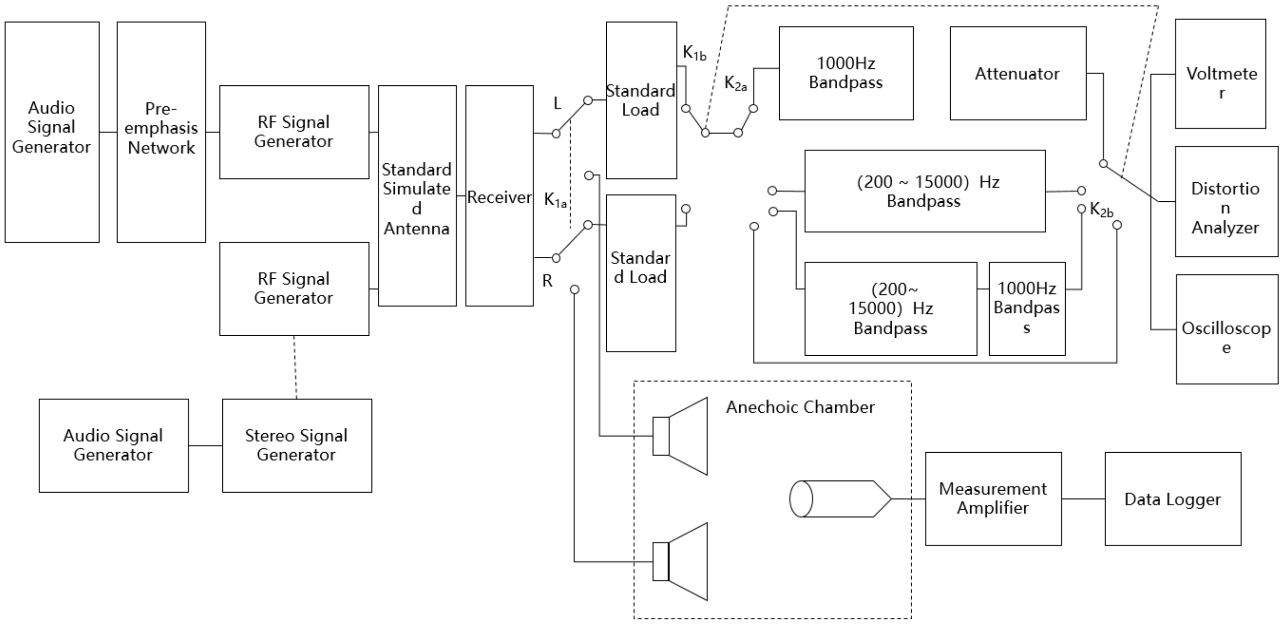

Figure 5. Schematic of FM Stereo Receiver Test Principle (from GB/T 6163-2011, page 9)

Automotive electronics R&D and manufacturing companies use signal generators to produce simulated FM stereo broadcasting signals to verify proper operation of FM stereo receivers.

Previously, such signal generators were dedicated instruments capable of generating FM signals, AM signals, and pilot-tone (AM-FM) stereo signals, however, as most were developed in the 1990s, these devices now face issues such as equipment aging, discontinued products, and maintenance difficulties.

RIGOL Solution

To address the product replacement challenges currently faced by automotive electronics R&D and manufacturing companies, RIGOL offers relevant products and solutions.

In the R&D testing phase, customizable FM stereo baseband signals can be generated using a function/arbitrary waveform generator. These signals are then sent to an RF signal generator for FM modulation to produce FM stereo signals with various required parameters. These signals are then fed into the in-vehicle infotainment or broadcast system for reception and demodulation, allowing for the testing of its core parameters.

Generate stereo audio baseband using a function/arbitrary waveform generator

Transmit the stereo audio baseband signal to the DSG800 RF signal generator to produce a stereo-modulated FM signal

Send the stereo-modulated FM signal to the car radio module for receiving and demodulation, and test relevant parameters

Figure 6. FM Stereo Generation Scheme for R&D Testing Phase

In the production phase, RIGOL offers the DSG800Z series RF signal source with integrated FM stereo baseband waveforms to improve testing efficiency. It includes key test functions essential for production testing, such as pre-defined single left channel (L) and single right channel (R) stereo waveform tables, allowing for efficient testing of the core performance of in-vehicle car radio equipment.

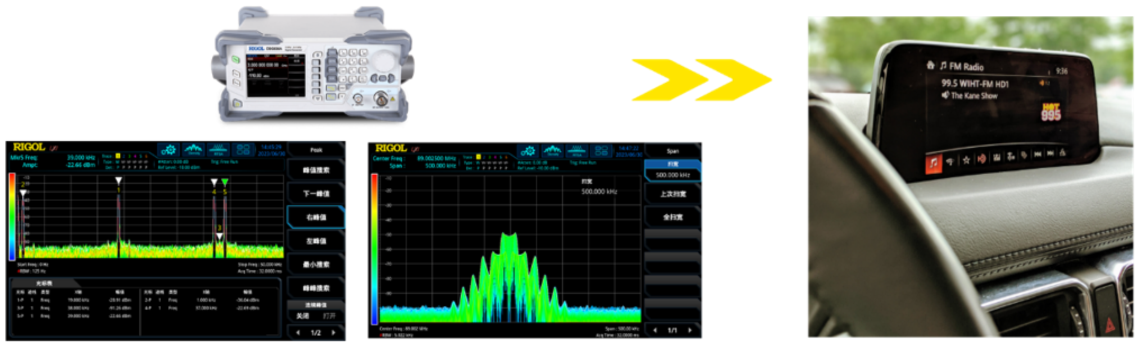

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Figure 7. FM stereo generation solution during the production testing stage

Conclusion

The solution provided by RIGOL can test various performance parameters of the FM stereo function, including the audio amplitude and frequency accuracy of single left/right channels, total harmonic distortion (THD) of the audio signal, signal-to-noise ratio (SNR), signal-to-noise and distortion ratio (SINAD), and left/right channel separation.

The simulated FM stereo signals generated by the DSG800 series RF signal generator feature high modulation quality and low baseband signal distortion, ensuring accurate test results for FM stereo receiving equipment.

Figure 7. RIGOL RF Source Product Family

RIGOL DSG800Z series RF signal generator utilizes Direct Digital Synthesis (DDS) technology to generate low-distortion audio and stereo basebands over a wide range.

Its core performance parameters show significant advantages compared to typical dedicated signal generators of this type:

	RIGOL		**Other Brand**	
	DSG800		8195/8196	
Frequency Range	9 kHz-1.5/2.1/3.6 GHz	√	100 kHz-165 MHz	
Frequency Resolution	0.01 Hz	√	100 Hz	
Frequency Accuracy	±2 ppm Option±5 ppb	√	±5 ppm	
Level Range	-110 dBm -13 dBm Available range: -110 dBm-20 dBm		-133 dBm – 13 dBm	√
Pre-emphasis	OFF / 25 us / 50 us / 75 us		OFF / 25 us / 50 us / 75 us	
Stereo Signal Generator	10 Hz-100 kHz	√	400 Hz、1 kHz	
DDS Stereo Signal Generator	10 Hz-100 kHz	√	20 Hz-15 kHz (Option)	

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