Keysight X-Series Signal Analyzer

This manual provides documentation for the following Analyzers:

N9040B UXA

N9030B PXA

N9020B MXA

N9010B EXA

N9000B CXA

N9063C
Analog Demod Measurement Application
Measurement Guide

KEYSIGHT TECHNOLOGIES

Notices

Trademark Acknowledgments

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Table of Contents

1 Demodulating AM, FM, ΦM, FM Stereo/RDS Signals

The Analog Demod measurement application provides the capability of demodulating AM (amplitude modulated), FM (frequency modulated), ΦM (phase modulated), and FM Stereo/RDS (Radio Data System) signals. These measurements provide functionalities that can generally be categorized as follows:

- Demodulating a modulated carrier and playing the modulating signal over a speaker (sometimes referred to as *tune and listen*)
- Displaying demodulated signals in both time and frequency domains
- Displaying modulation metrics
- Displaying the RDS information in FM Stereo/RDS signals

The following topics can be found in this section:

Setting Up and Making a Measurement

Making the Initial Signal Connection

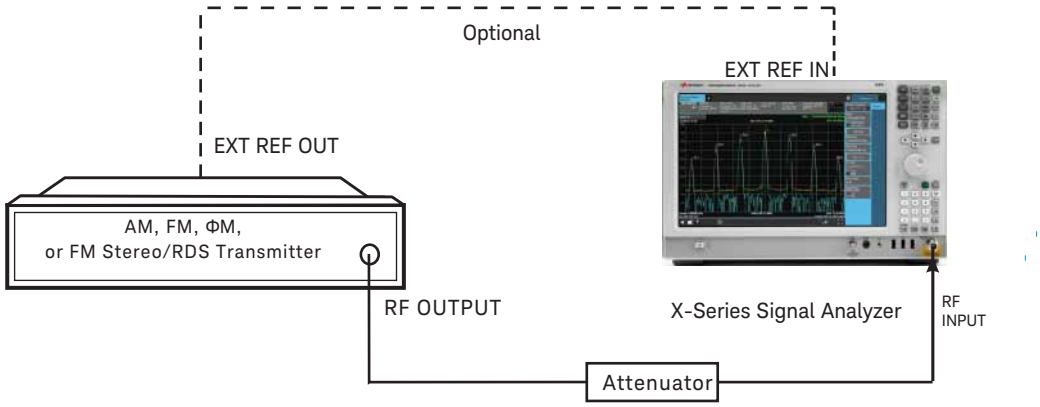
Set the AM, FM, ΦM, or FM Stereo/RDS transmitter under test to transmit the RF power. Connect the transmitting signal to the signal analyzer as shown below in Figure 1-1.

CAUTION

Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connector on the instrument front panel.

1. Connect the output AM, FM, ΦM, or FM Stereo/RDS transmitter to the RF input port of the signal analyzer using appropriate cables, attenuators, and adapters.
2. (Optional) If there is a frequency reference port on the transmitter, connect it to the EXT REF IN port on the signal analyzer for frequency synchronization.

Figure 1-1 AM, FM, ΦM, or FM Stereo/RDS Measurement System



After making the connection, see the **Input/Output** menu for details on selecting input ports and the **Amplitude** menu for details on setting the internal attenuation to prevent overloading the analyzer.

Using Analyzer Mode and Measurement Presets

To set your current measurement mode to a known factory default state, press **Mode Preset**. This initializes the analyzer by returning the mode setup and all of the measurement setups in the mode to the factory default parameters.

To preset the parameters that are specific to an active, selected measurement, press **Meas Setup**, **Meas Preset**. This returns all the measurement setup parameters to the factory defaults, but only for the currently selected measurement.

Demodulating an AM Signal

This section demonstrates how to demodulate and listen to an AM signal. You can tune to an AM signal and view the results of the detector output displayed in the quad-view window or in single-window format.

Alternatively, the demodulated signal is also available as an audio output (to the speaker or headphone jack) and as video output (on the rear panel).

The signal under test is a 680 kHz signal with AM depth of 50% and AM rate of 1 kHz. Note that if you are using a broadcast AM signal in the United States, for example, the AM channels are broadcasting between 550 kHz and 1650 kHz.

Step	Action	Notes
1. Select Analog Demod mode.	– Press **Mode/Meas**, **Analog Demod**, **OK**.	The default settings for Analog Demod Mode are the AM measurement and Quad View
2. Preset the mode.	– Press **Mode Preset**.	
3. Set the center frequency of the AM signal.	– Press **Center Freq** and enter **680**, **kHz**.	
4. Adjust the sweep time and view the measurement results as in the figure below.	– Press **Sweep**. – Press **Demod Wfm Sweep Time** and enter **2 ms**.	This is the default setting.

Step	Action	Notes
5. Listen to the demodulated AM signal.	– Press **Meas Setup**, **Advanced Tab** – Toggle **Demod to Speaker** to **On**	You may need to adjust the volume as necessary.

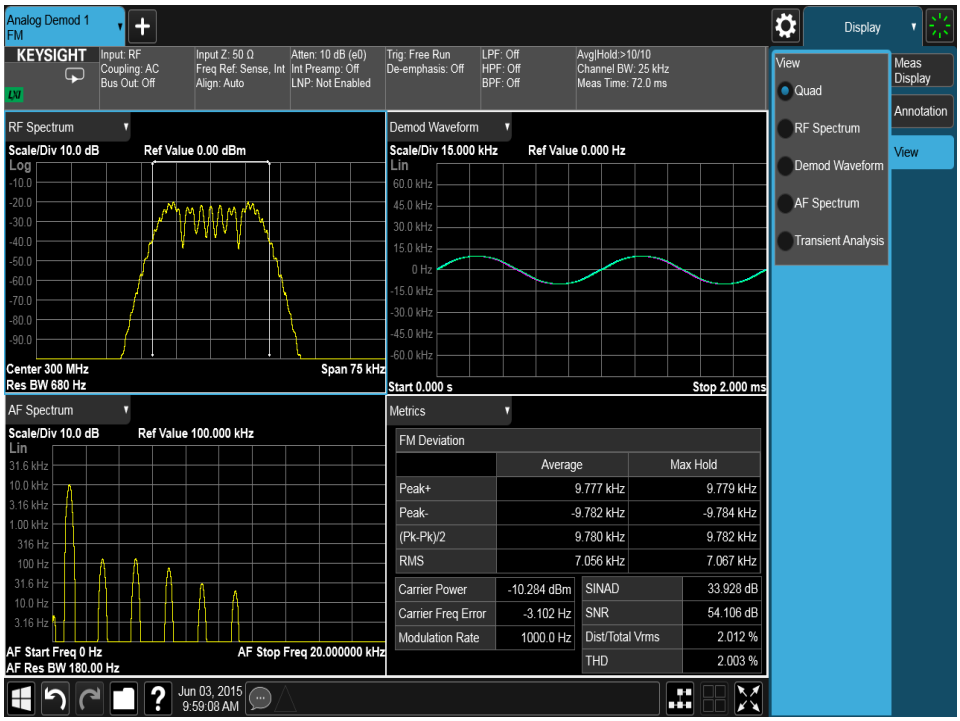
Demodulating an FM Signal

This section demonstrates how to demodulate and listen to an FM signal. You can tune to an FM signal and view the results of the detector output displayed in the quad-view window or single-window format.

Alternatively, the demodulated signal is also available as an audio output (to the speaker or headphone jack) and as video output (on the rear panel).

The signal under test is a signal at 300 MHz with FM deviation of 10 kHz and FM rate of 1 kHz. Note that if you are using a broadcast FM signal in the United States, for example, the FM channels are broadcasting between 87.7 MHz and 107.7 MHz.

Step	Action	Notes
1. Select Analog Demod mode.	– Press **Mode/ Meas**, **Analog Demod**.	
2. Preset the mode.	– Press **Mode Preset**.	
3. Select FM measurement.	– Press **Mode/ Meas**, **FM, OK**.	The Quad view is the default setting.
4. Set the center frequency to the center of the FM signal.	– Tap **Center Freq** and enter **300**, **MHz**.	
5. Adjust the sweep time and view the measurement result as in the figure below.	– Press **Sweep**, **Demod Wfm Sweep Time**, **2**, **ms**.	This is the default setting.



Step	Action	Notes
6. Listen to the demodulated FM signal.	– Press **Meas Setup**, **Advanced Tab** – Toggle **Demod to Speaker** to **On**	You may need to adjust the volume as necessary.

Demodulating an FM Stereo/RDS Signal

This section demonstrates how to demodulate and listen to an FM Stereo signal and view key messages carried in RDS (Radio Data System). You can tune to an FM Stereo/RDS signal and view the measurement results of the multiplexed signal, the mono signal, the stereo signal, the left and right channel of the stereo signal, and the RDS messages in separate views.

Alternatively, the demodulated FM Stereo signal is also available as an audio output (to the speaker or headphone jack).

Measurement procedures for two typical FM Stereo/RDS signals are introduced here:

"Measuring L Only FM Stereo/RDS Signals" on page 13

"Measuring L=R FM Stereo/RDS Signals" on page 19

Measuring L Only FM Stereo/RDS Signals

The parameters of the signal under test are:

FM reference deviation: 75 kHz

Pilot deviation: 10%

Pilot frequency: 19 kHz

Stereo frequency: 38 kHz

Left only tone: 1.0 kHz

RDS deviation: 6%

RDS frequency: 57 kHz

Step	Action	Notes
1. Select Analog Demod mode	– Press **Mode/Meas**, **Analog Demod**.	
2. Preset the mode.	– Press **Mode Preset**.	
3. Select FM Stereo/RDS measurement.	– Press **Mode/Meas**, **FM Stereo/RDS**.	
4. Set the center frequency to the center of the signal and set the AF stop frequency.	– Press **FREQ Channel**, **Center Freq**, 98, **MHz**. – Press **AF Stop Freq**, 65, **kHz**.	AF start frequency and AF stop frequency settings determine the span of the X axis in AF Spectrum window in MPX, Mono, Stereo, Left, and Right views.
5. Set the FM reference deviation.	– Press **Meas Setup**, **Advanced**, **Ref Deviation**, 75, **kHz**.	

Step	Action	Notes
6. View the measurement result of the multiplexed signal.	– Press **Display, View**, **MPX**.	To display only the current trace in the Demod Waveform window, press **Meas Setup** and toggle **Averaging** to **Off**.

The figure below shows the measurement results of the multiplexed signal, including the mono part, stereo part, RDS/RBDS, and pilots. There are four windows:

– RF Spectrum window (top left) displays the RF spectrum of the multiplexed signal.

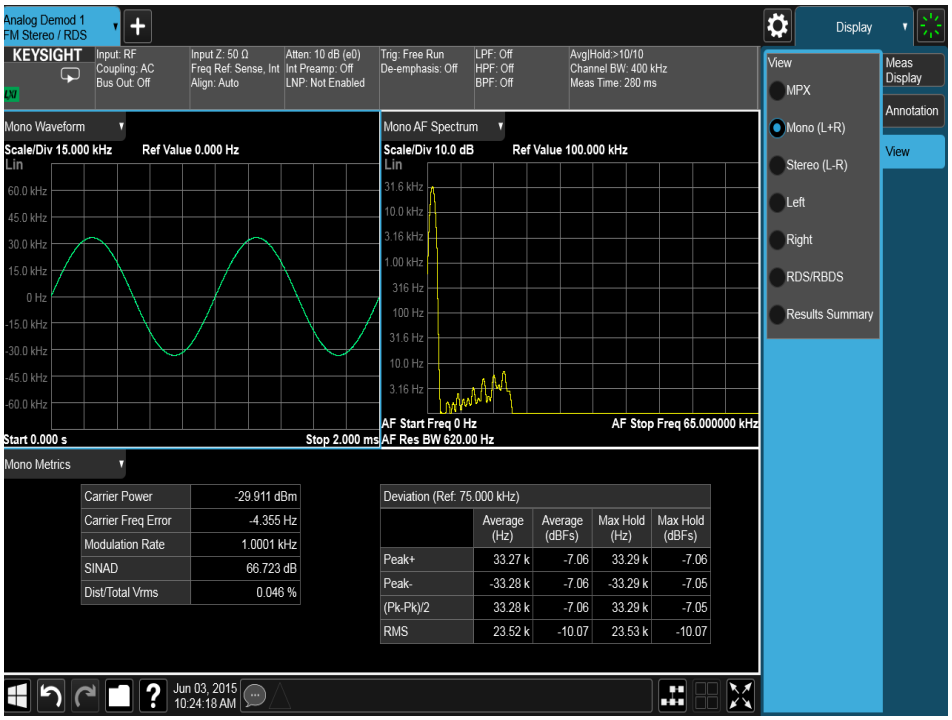
– Demod Waveform window (top right) displays the baseband modulating signal in time domain. There are four traces in this window: maximum trace (in cyan), minimum trace (in magenta), average trace (in green), and current trace (in yellow).

– AF Spectrum window (bottom left) displays the modulating signal in frequency domain.

– Metric window (bottom right) displays the numeric measurement results.

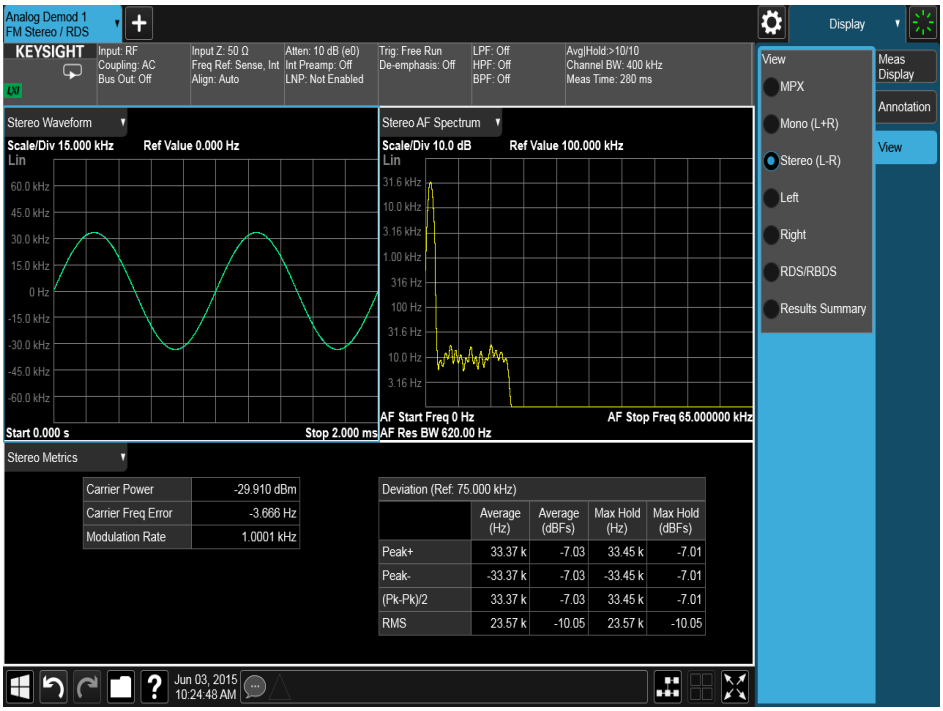
7. View the mono part of the multiplexed signal which corresponds to L+R.	– Press **Display**, **View, Mono**.	

Step	Action	Notes

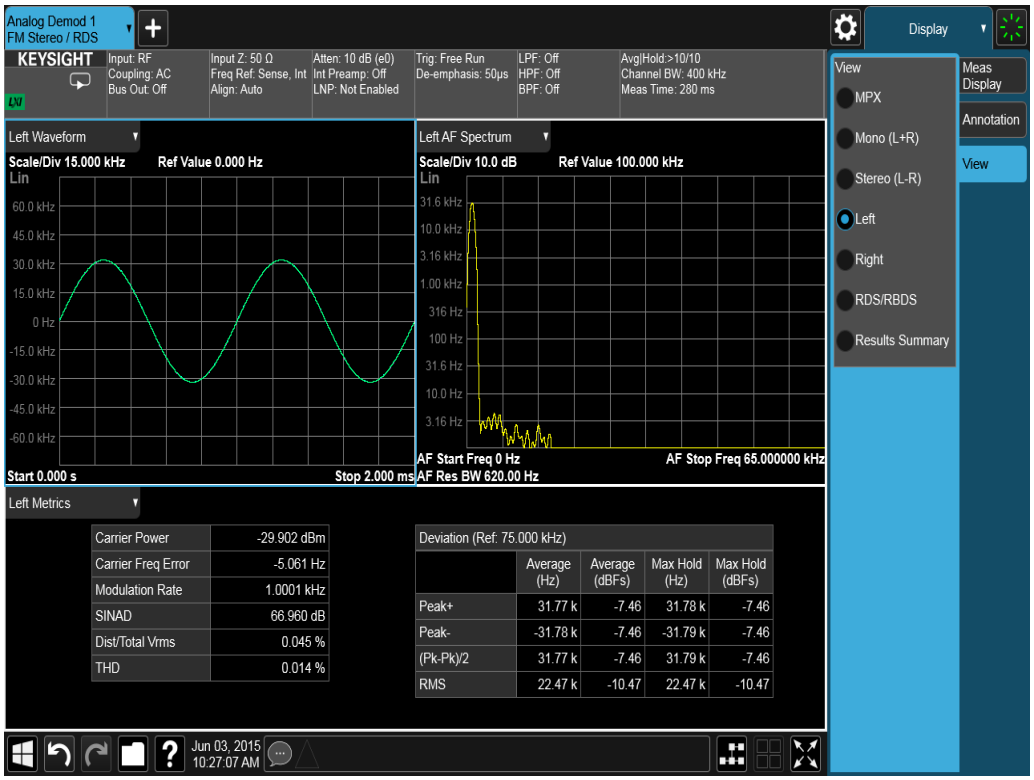


8. View the stereo part of the multiplexed signal which corresponds to L-R.

– Press **Display**, **View, Stereo**.

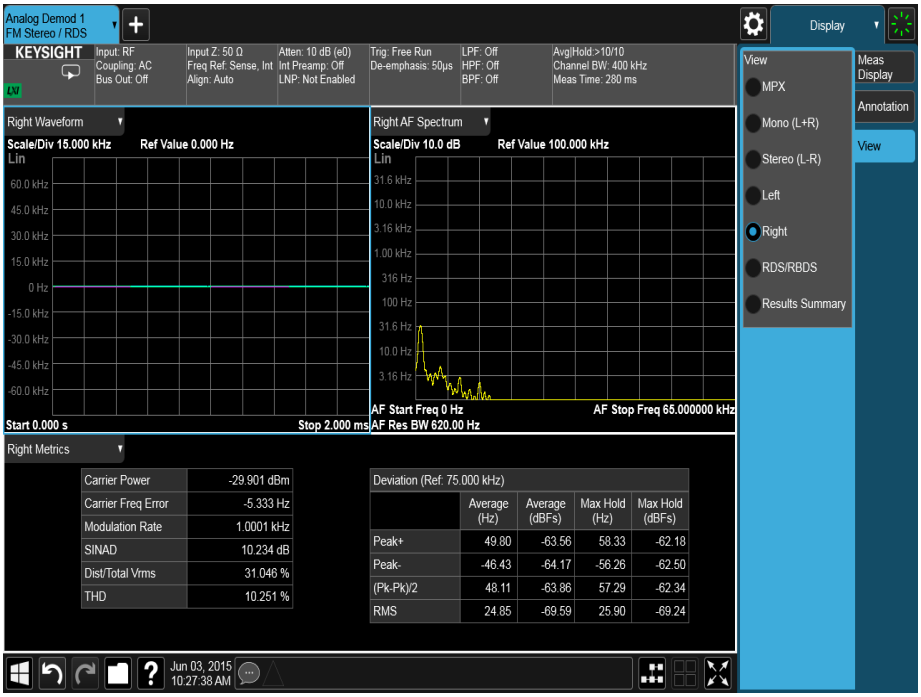


Step	Action	Notes
9. (Optional) Set the baseband filters to improve the measurement results.	– Press **Meas Setup**, **Filters**.	The highpass filter, lowpass filter, and bandpass filter can be combined as you like.
10. If pre-emphasis is used in the signal under test, set to use de-emphasis in the signal analyzer.	– Press **Meas Setup**, **Filters**, **De-Emphasis** and choose the appropriate de-emphasis filter.	
11. View measurement results of the left channel.	– Press **Display**, **View, Left**.	



12. View measurement results of the right channel.	– Press **Display**, **View, Right**.	The audio in the test signal is an L-only tone, so in the results of the right channel, the demod waveform is almost zero.

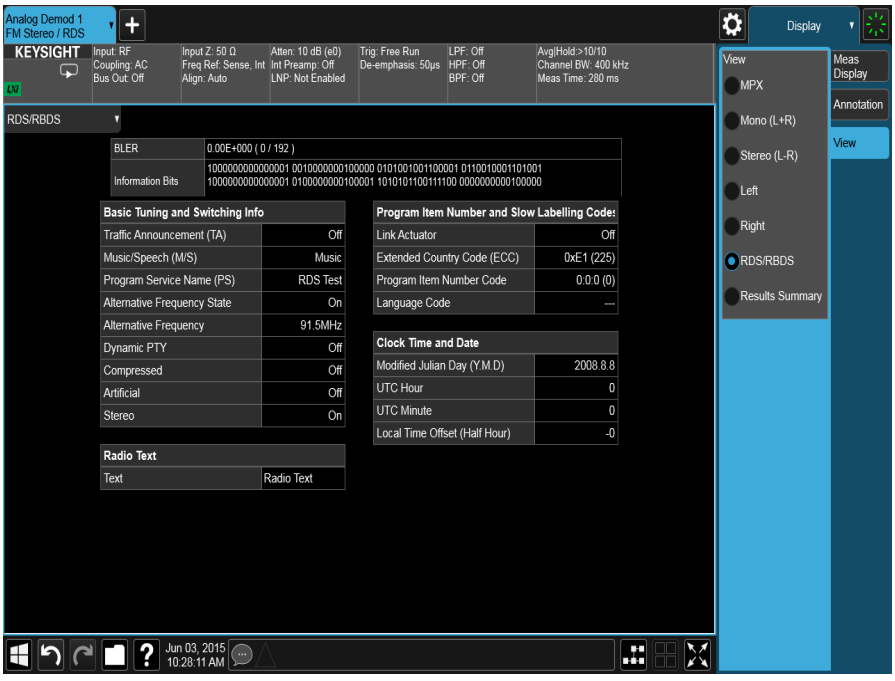
Step	Action	Notes



13. View the RDS/RBDS results.

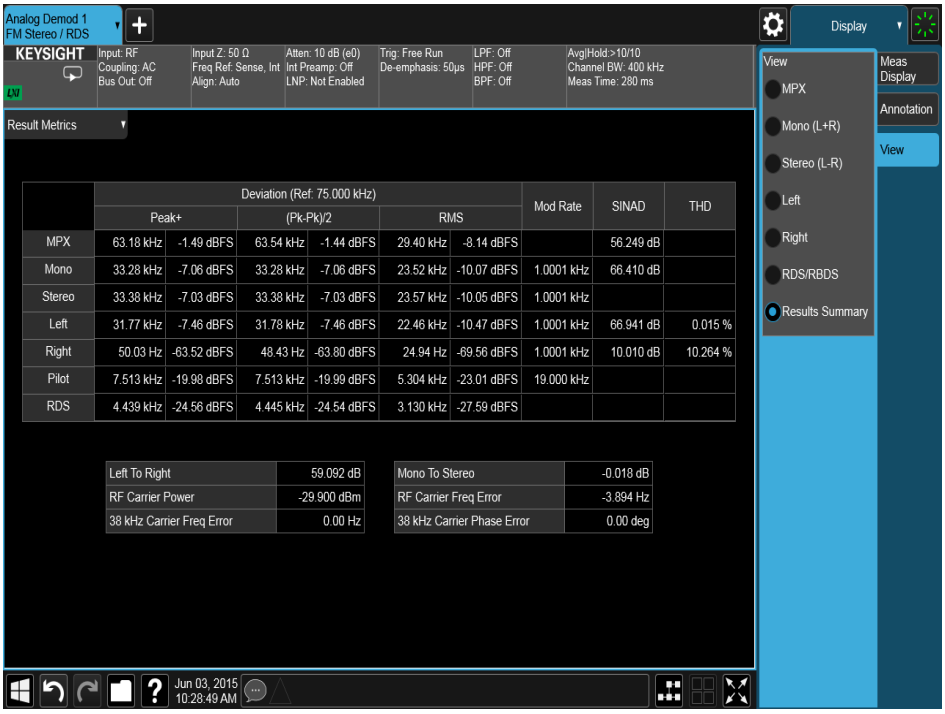
– Press **Display**, **View, RDS/RBDS**.

The figure below displays the BLER result and the information bits in the upper part and key RDS messages like basic tuning and switch information, radio text, and so on in the lower part. For more information, refer to "Basic Structure of RDS" on page 31 and "BLER" on page 31.



Step	Action	Notes
14. View a summary of the numeric measurement results.	– Press **Display**, **View, Results Summary**.	

NOTE In this view, the left to right separation result is displayed as "Left to Right" and the mono to stereo crosstalk is displayed as "Mono to Stereo". Normally, the left to right separation test is taken when the audio signal under test is L only or R only; mono to stereo crosstalk test is taken when the audio signal under test is L=R or L=-R.



15. Listen to the demodulated FM stereo signal.	– Press **Meas Setup**, **Advanced Tab** – Toggle **Demod to Speaker** to **On**	You may need to adjust the volume as necessary.

Measuring L=R FM Stereo/RDS Signals

The parameters of the signal under test are as below.

FM reference deviation: 75 kHz

Pilot deviation: 10%

Pilot frequency: 19 kHz

Stereo frequency: 38 kHz

Left = Right tone: 1.0 kHz

RDS deviation: 6%

RDS frequency: 57 kHz

Step	Action	Notes
1. Select Analog Demod mode.	– Press **Mode**, **Analog Demod**.	
2. Preset the mode.	– Press **Mode Preset**.	
3. Select FM Stereo/RDS measurement.	– Press **Mode/Meas**, **FM Stereo/RDS**.	
4. Set the center frequency to the center of the signal and set the AF stop frequency.	– Press **FREQ**, **Center Freq**, 98, **MHz**. – Press **AF Stop Freq**, 65, **kHz**.	AF start frequency and AF stop frequency settings determine the span of the X axis in AF Spectrum window in MPX, Mono, Stereo, Left, and Right views.
5. Set the FM reference deviation.	– Press **Meas Setup**, **Advanced**, **Ref Deviation**, 75, **kHz**.	
6. View the measurement result of the multiplexed signal.	– Press **Display, View**, **MPX**.	To display only the current trace in the Demod Waveform window, press **Meas Setup** and toggle **Averaging** to **Off**.

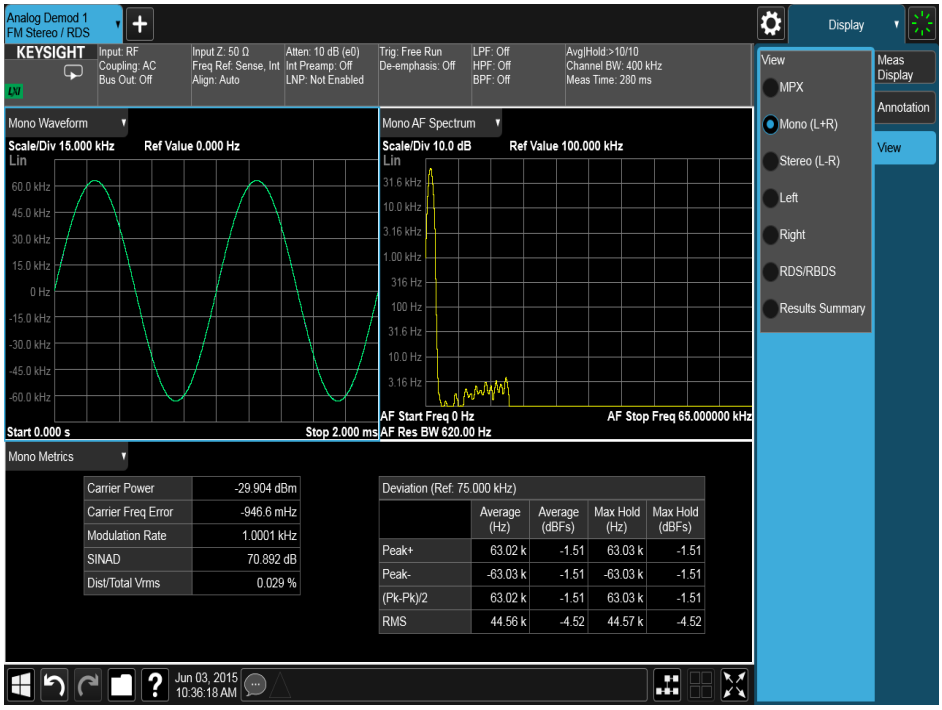
Step	Action	Notes

The figure below shows measurement results of the multiplexed signal, including the mono part, the stereo part, RDS/RBDS, and pilots. There are four windows:

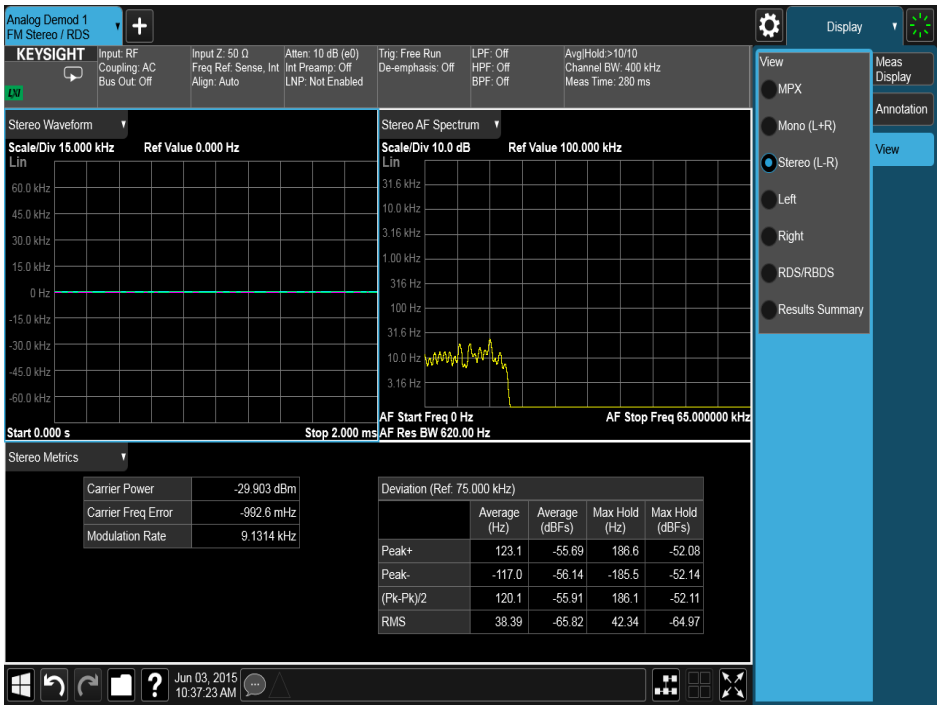
- RF Spectrum window (top left) displays the RF spectrum of the multiplexed signal.
- Demod Waveform window (top right) displays the baseband modulating signal in time domain. There are four traces in this window: maximum trace (in cyan), minimum trace (in magenta), average trace (in green), and current trace (in yellow).
- AF Spectrum window (bottom left) displays the modulating signal in the frequency domain.
- Metric window (bottom right) displays the numeric measurement results.

7. View the mono part of the multiplexed signal which corresponds to L+R.	– Press **Display**, **View, Mono**.	

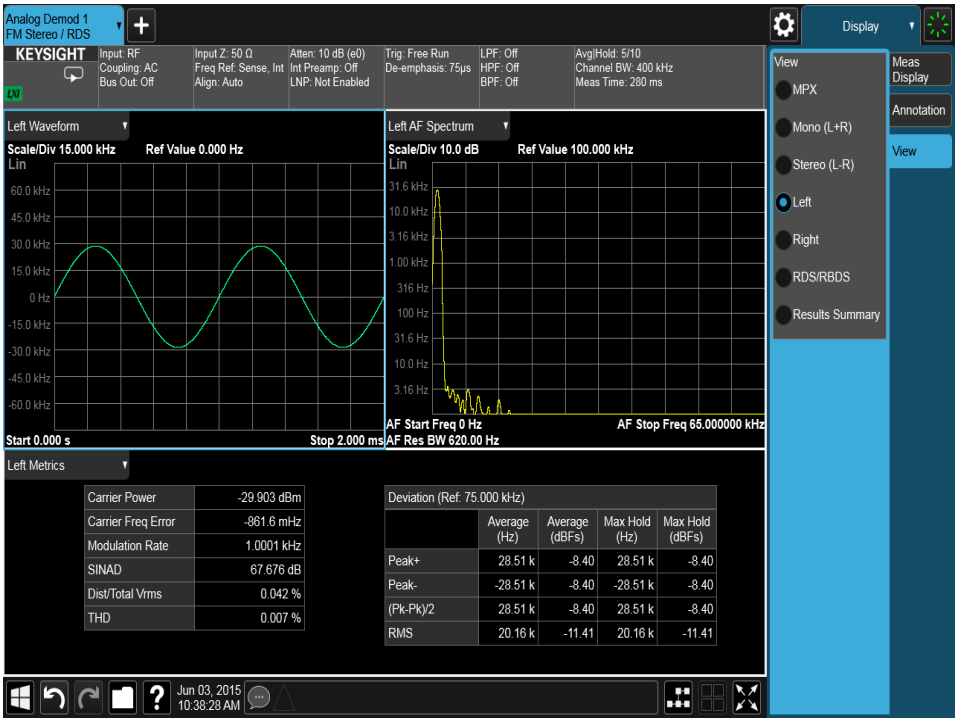
Step	Action	Notes



8. View the stereo part of the multiplexed signal which corresponds to L- R.	– Press **View/Display**, **Stereo**.	



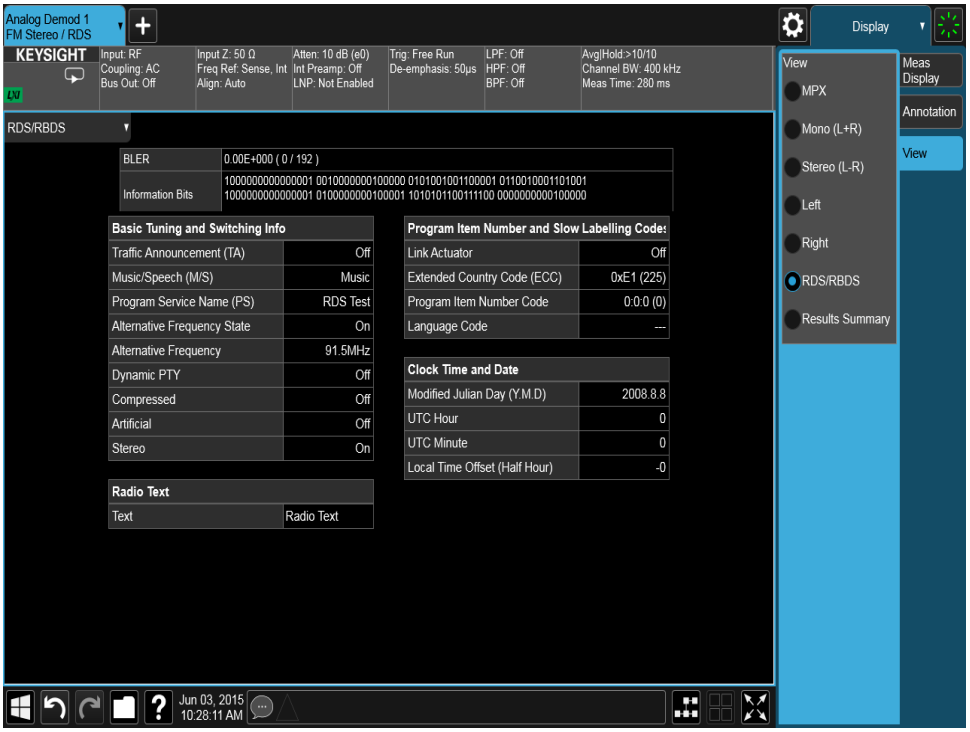
Step	Action	Notes
9. (Optional) Set the baseband filters to improve the measurement results.	– Press **Meas Setup**, **Filters**.	The highpass filter, lowpass filter, and bandpass filter can be combined as you like.
10. If pre-emphasis is used in the signal under test, set to use de-emphasis in the signal analyzer.	– Press **Meas Setup**, **Filters**, **De-Emphasis** and choose the appropriate de-emphasis filter.	
11. View the measurement results of the left channel.	– Press **Display**, **View, Left**.	In this test case, the left channel equals to the right channel.



12. View the RDS/RBDS results.	– Press **Display**, **View, RDS/RBDS**.	

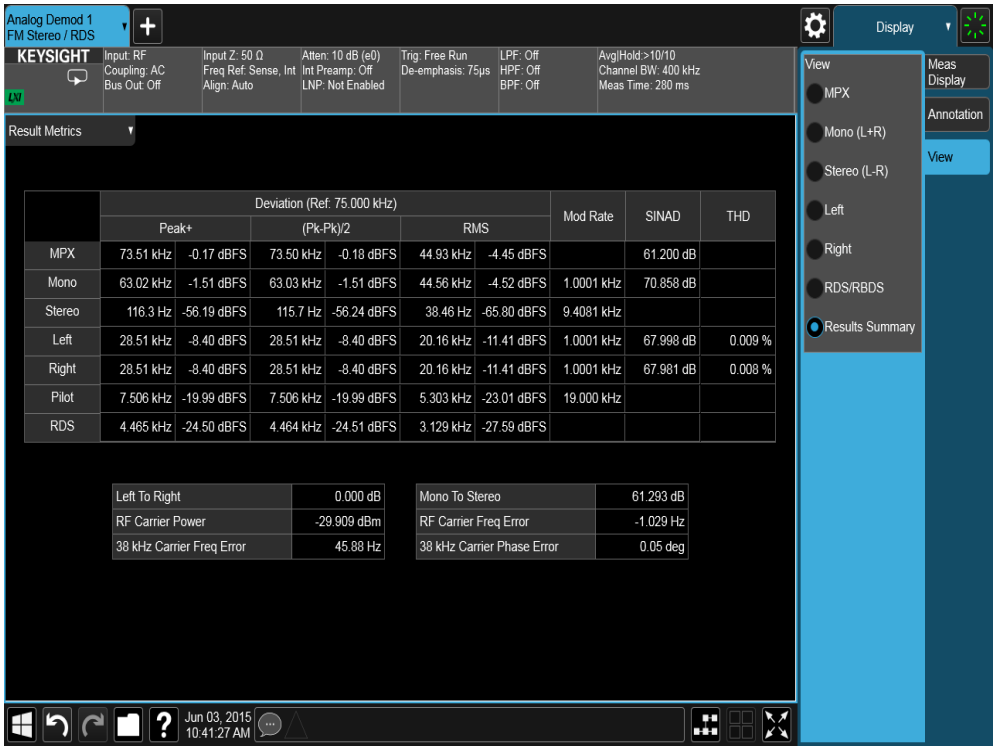
Step	Action	Notes

The figure below displays the BLER result and the information bits in the upper part and key RDS messages like basic tuning and switch information, radio text, and so on in the lower part. For more information, refer to "Basic Structure of RDS" on page 31 and "BLER" on page 31.



13. View a summary of the numeric measurement results.	– Press **Display**, **View, Result Summary**.	

Step	Action	Notes
NOTE	In this view, the left to right separation result is displayed as "Left to Right" and the mono to stereo crosstalk is displayed as "Mono to Stereo". Normally, the left to right separation test is taken when the audio signal under test is L only or R only; mono to stereo crosstalk test is taken when the audio signal under test is L=R or L=-R.	



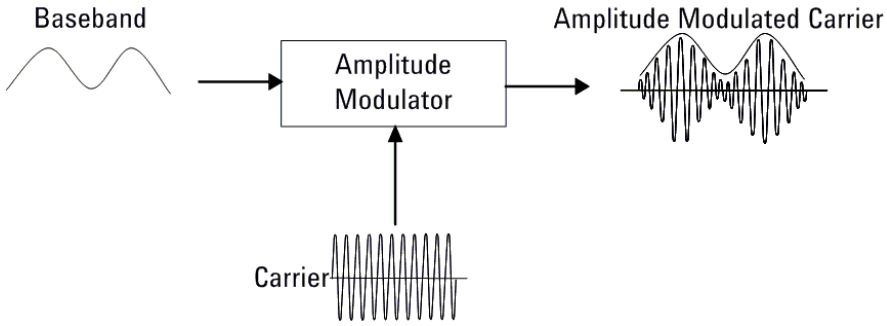
14. Listen to the demodulated FM stereo signal.	– Press **Meas Setup**, **Advanced Tab** – Toggle **Demod to Speaker** to **On**	You may need to adjust the volume as necessary.

2 Concepts

The following topics can be found in this section:

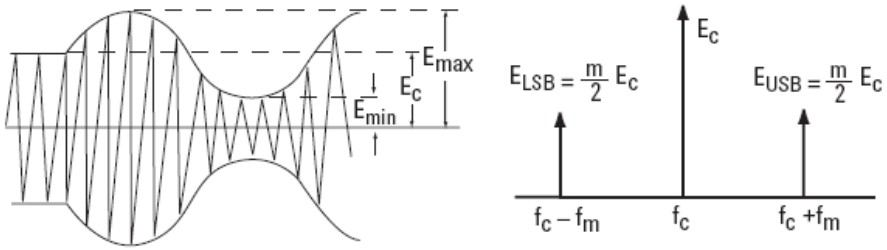
AM Concepts

Figure 2-1 AM waveform



In AM (Amplitude Modulation), the instantaneous amplitude of the modulated carrier signal changes in proportion to the instantaneous amplitude of the information signal.

Figure 2-2 Calculation AM index in time and frequency domain



The modulation index "m" represents the amount of modulation or the degree to which the information signal modulates the carrier signal. The index for an AM signal can be calculated from the amplitudes of the carrier and either of the sidebands by the equation:

Equation 2-1

$$m = \frac{E_{max} - E_c}{E_c} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} = \frac{E_{USB} + E_{LSB}}{E_c} = \frac{2E_{SB}}{E_c}$$

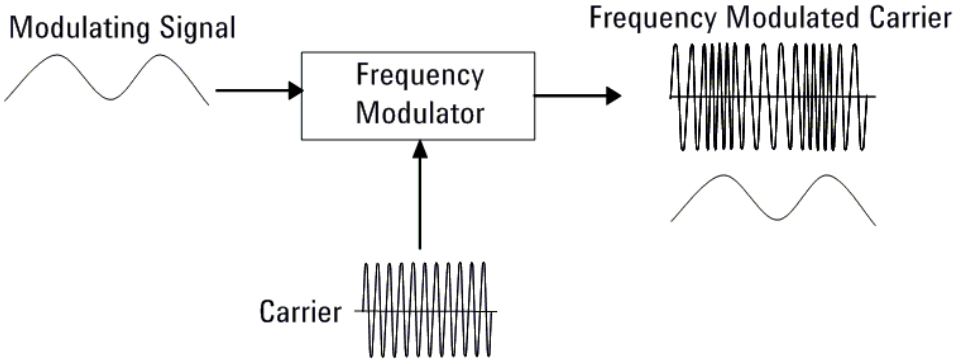
For 100% modulation, the modulation index is 1.0, and the amplitude of each sideband will be one-half of the carrier amplitude expressed in voltage. On a decibel power scale, each sideband will thus be 6 dB less than the carrier, or one-fourth the power of the carrier. Since the carrier power does not change with amplitude modulation, the total power in the 100% modulated wave is 50% higher than in the unmodulated carrier. The relationship between m and the logarithmic display can be expressed as:

Equation 2-2

$$(E_{SB} \S E_c)dB + 6dB = 20\log m$$

FM Concepts

Figure 2-3 FM waveform



FM (Frequency Modulation) and PM (Phase Modulation) belong to angle modulation. In FM, the instantaneous frequency deviation of the modulated carrier signal changes in proportion to the instantaneous amplitude of the modulating signal. And in PM, the instantaneous phase deviation of the modulated carrier with respect to the phase of the unmodulated carrier is directly proportional to the instantaneous amplitude of the modulating signal.

The modulation index for angle modulation, β, is expressed by this equation:

Equation 2-3

$$\beta = \Delta \times f_p / f_m = \Delta \Phi_p$$

Where Δfp is the peak frequency deviation, fm is the frequency of the modulating signal, and $\Delta\phi$p is the peak phase deviation.

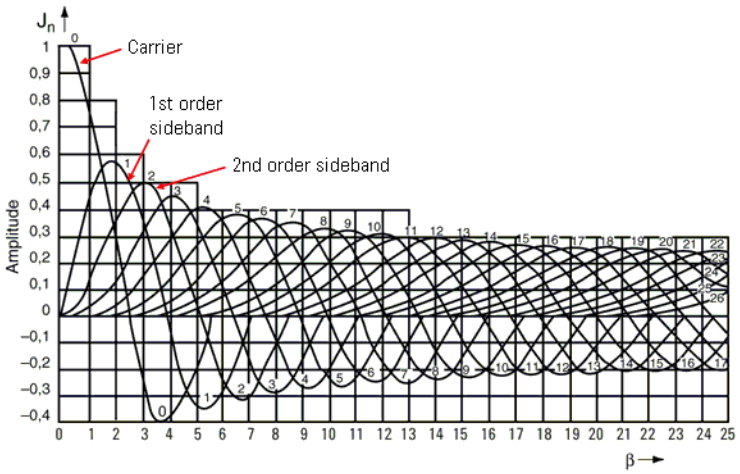
This expression tells us that the angle modulation index is really a function of phase deviation, even in the FM case. Also, the definitions for frequency and phase modulation do not include the modulating frequency. In each case, the modulated property of the carrier, frequency or phase, deviates in proportion to the instantaneous amplitude of the modulating signal, regardless of the rate at which the amplitude changes. However, the frequency of the modulating signal is important in FM and is included in the expression for the modulating index because it is the ratio of peak frequency deviation to modulation frequency that equates to peak phase.

Unlike the modulation index for AM, there is no specific limit to the value of β, since there is no theoretical limit to the phase deviation; thus there is no equivalent of 100% AM. However, in real world systems there are practical limits.

Unlike AM, which is a linear process, angle modulation is nonlinear. This means that a single sine wave modulating signal, instead of producing only two sidebands, yields an infinite number of sidebands spaced by the modulating frequency.

The Bessel function graph shows the amplitudes of the carrier and the sidebands as a function of the modulation index, β. The spectral components, including the carrier, change their amplitudes as the modulation index varies.

Figure 2-4 Carrier and sideband amplitude for angle-modulated signals



In theory, for distortion-free detection of the modulating signal, all the sidebands must be transmitted. However, in practice, the sideband amplitudes become negligibly small beyond a certain frequency offset from the carrier, so the spectrum of a real-world FM signal is not infinite.

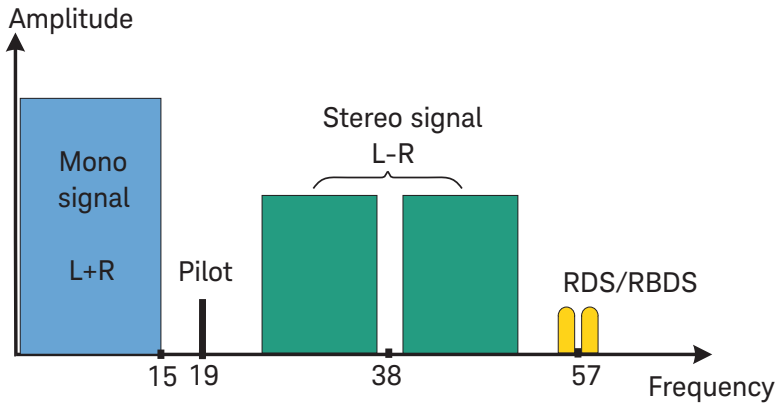
FM Stereo/RDS Concepts

FM stereo is an enhancement of FM using stereo multiplexing. An FM stereo signal carries stereophonic programs in which different contents are transmitted for L (left) and R (right) audio channels.

RDS (Radio Data System) is the text information such as traffic, weather, and radio station information carried in FM signals. This information can be displayed on the screen of the end-user's device.

The following figure shows the baseband spectrum of the FM stereo signal including RDS data.

Figure 2-5 Baseband spectrum of the FM Stereo/RDS signal



FM Stereo

The FM stereo multiplexed signal consists of a mono (L+R) signal, a stereo (L-R) signal, and a pilot signal.

As shown in Figure 2.5, the mono (L+R) signal occupies the lower part of the baseband spectrum (50 Hz ~ 15 kHz) to keep backward compatibility with the previously monophonic FM systems. The (L-R) signal is amplitude modulated onto a suppressed subcarrier at 38 kHz. A pilot signal is transmitted at 19 kHz and is used by the receiver to identify a stereo transmission and reconstruct L and R audio signals from the multiplexed signal.

In the receiver, the (L+R) signal is added to the (L-R) signal to get the L signal, and subtracts the (L-R) signal to get the R signal.

RDS/RBDS

The standard documents for RDS and RBDS are as follows:

- IEC 62106: Specification of the radio data system (RDS) for VHF/FM sound broadcasting in the frequency range from 87.5 to 108.0 MHz.
- EIA/NAB NRSC: United States RBDS standard - Specification of the radio broadcast data system (RBDS).

RBDS is the United States version of RDS. Both RDS and RBDS are intended for application to VHF/FM sound broadcasts in the range 87.5 MHz to 108.0 MHz which may carry either stereophonic or monophonic programs.

The main objectives of RDS/RBDS:

– To enhance functionality for FM receivers;

– To make the receivers more user-friendly by using features such as PI (program identification), PS (program service) name display, and if applicable, automatic tuning for portable and car radios.

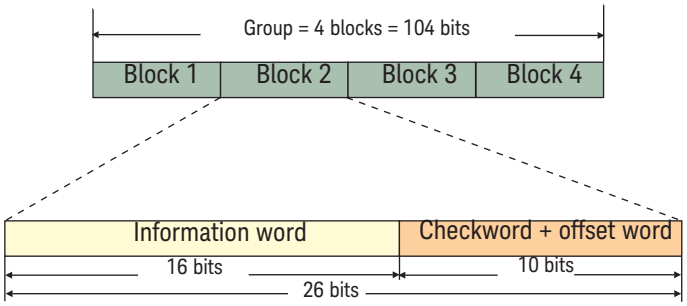
As shown in Figure 2-5, RDS/RBDS uses the 57 kHz subcarrier to carry the data at 1.1875 kbps bitrate. The 57 kHz is chosen to be the third harmonic of the pilot tone. The deviation range of the FM carrier due to the unmodulated RDS/RBDS subcarrier is from ±1.0 kHz to ±7.5 kHz.

Basic Structure of RDS

The basic structure of RDS is shown in Figure 2-6, in which the largest element is called a group including 4 blocks of 26 bits each. Each block comprises an information word (16 bits) and a checkword (10 bits).

The information word is used to transmit information to the end user. The 10-bit checkword plus offset word are used to provide error protection and block and group synchronization information.

Figure 2-6 Basic structure of RDS



BLER

BLER (block error rate) is the ratio of the number of un-correctable blocks to the total number of blocks received. Normally, BLER should be less than 5%.

Modulation Distortion Measurement Concepts

Purpose

This measurement is used to measure the amount of modulation distortion contained in the modulated signal by determining the ratio of harmonic and noise power to fundamental power. This measurement verifies the modulation quality of the signal from the DUT.

Measurement Technique

Modulation Distortion is defined as:

Equation 2-4

$$\%_{ModulationDistortion} = \sqrt{\frac{P_{total} - P_{signal}}{P_{total}}} \times 100\%$$

where: P_{total} = the power of the total signal,

P_{signal} = the power of the wanted modulating signal, and

P_{total} - P_{signal} = total unwanted signal which includes harmonic distortion and noise.

First, the received signal is demodulated and filtered to remove DC. Then the filtered signal is transformed by an FFT into the frequency domain. Next, total power in the total filter band is measured as P_{total}, the peak power of the modulated signal is computed as P_{signal}, the square root of the ratio of P_{total} - P_{signal} to P_{total} is calculated. The result is the signal's modulation distortion. It can be expressed as dB or %.

Modulation SINAD Measurement Concepts

Purpose

Modulation SINAD (SIgnal to Noise And Distortion) measures the amount of Modulation SINAD contained in the modulated signal by determining the ratio of fundamental power to harmonic and noise power. Modulation SINAD is the reciprocal of the modulation distortion provided by the Modulation Distortion measurement. This is another way to quantify the quality of the modulation process.

Measurement Technique

Modulation SINAD is defined as:

Equation 2-5

$$dB_{ModulationSINAD} = 20 \times \log \sqrt{\frac{P_{total}}{P_{total} - P_{signal}}}$$

where: P_{total} = the power of the total signal,

P_{signal} = the power of the wanted modulating signal, and

P_{total} - P_{signal} = the total unwanted signals which include harmonic distortion and noise.

First, the received signal is demodulated and filtered to remove DC, then the filtered signal is transformed by an FFT into the frequency domain. Next, total power in the total filter band is measured as P_{total}, the peak power of the modulated signal is computed as P_{signal}, the square root of the ratio of P_{total} to P_{total} - P_{signal} is calculated. The result is the signal's Modulation SINAD. It can be expressed as dB.

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