application
note

Intermodulation testing with the IFR 2309 100 MHz to 2.4 GHz FFT Analyzer

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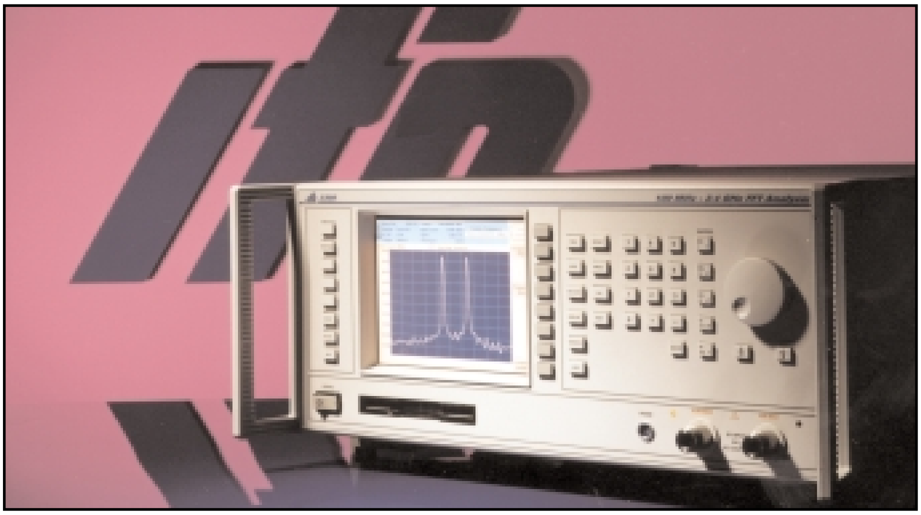

This application note details how 2309 and 2026 can be used to make intermodulation measurements more accurately than spectrum analyzers. It explains how the deficiencies with spectrum analyzers are overcome by using the 2309 approach.

Introduction

Although spectrum analyzers can be used to make intermodulation measurements there are occasions when their performance, speed and accuracy are unacceptable for the reasons described below. In these cases the 2309 can provide a much better solution to demanding measurements with much greater accuracy.

Measuring Intermodulation

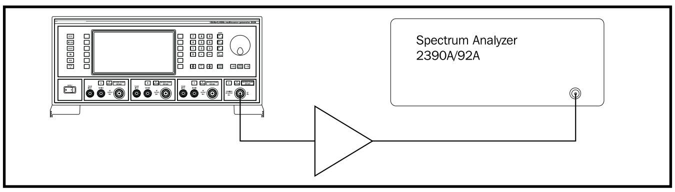

Fig 1 Typical intermod set up using 2026

In principle measuring intermodulation should be a straight forward problem. The outputs of two or more signal generators are combined together and applied to the device under test. The output from the device can then be measured using a spectrum analyzer. Getting a test system together can be considerably simplified by using the 2026 Multicarrier signal generator to replace up to three signal generators, the combiner and the associated cabling.

However, the performance of the spectrum analyzer can restrict the user's ability to measure intermodulation effects accurately because of the errors in the level measuring systems used in a spectrum analyzer and its inherent noise.

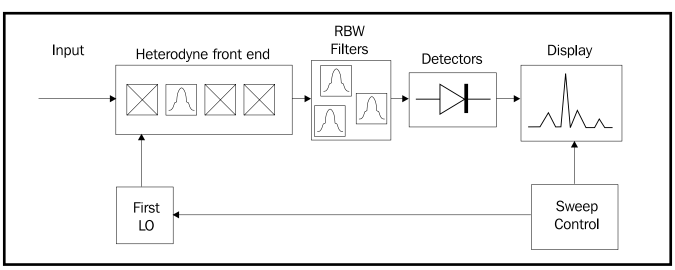

Fig 2 Typical spectrum analyzer architecture.

The level errors arise from measuring both the level of the wanted signal and the level of the intermodulation products. Spectrum analyzers use a receiver architecture which requires several frequency conversions to generate the final signal, whose amplitude is measured. This complexity, shown in figure 2 above, is required to ensure the spectrum analyzer has no spurious or image responses, but results in a very long RF chain which has significant frequency response characteristics. Although software can be used to correct some of the response there will still be residual errors, including those due to environmental factors. It is often difficult to extract this information from the analyzer data sheet since the numbers are usually quoted under specific conditions, which may or may not correspond to the ones the user requires, and often the errors are broken up into frequency response, attenuator, input VSWR and reference errors which need adding together. It is not uncommon for the level measurement errors to be between 2 dB and 5 dB depending on frequency.

Since the intermodulation effects are described relative to the output power of the device under test and the level of the intermodulation product is very dependent on the power level, substantial measurement errors can result.

A second problem on level measurements arises because the spectrum analyzer needs to measure low level as well as high level signals. On a 10 dB per division display format a typical specification is 0.15 dB/dB of vertical scale and 1.5 dB error over a 60 dB range. This error has to be added to the frequency response errors.

If the intermodulation products generated are at a low level it is also wise to be careful about changing the resolution BW of the analyzer between measurement of the carrier signal and measurement of the intermodulation product. Changing the filter can introduce additional reference level errors.

Noise and Internal Intermodulation

Noise can introduce additional limitations to the spectrum analyzer. The complex architecture of a spectrum analyzer leads to limitations in the floor noise performance. A typical spectrum analyzer may have a specified noise performance of -100 dBc/Hz. If a signal is measured in a filter with a noise bandwidth of 1 kHz then the noise has a displayed level of -70 dBc and intermodulation products can be masked or uncertainties introduced in the level measurement. These effects can be reduced by narrowing the filter bandwidth but that will also have the effect of increasing the measurement time.

The spectrum analyzer is also capable of generating its own intermodulation products, principally from the input mixer, at the same frequencies as the unit under test. A typical spectrum analyzer is specified at -80 dBc for a -40 dBm signal (typically -30 dBm with 10 dB additional attenuation) to the mixer, equivalent to a TOI of 0 dBm. Reducing the signal to the

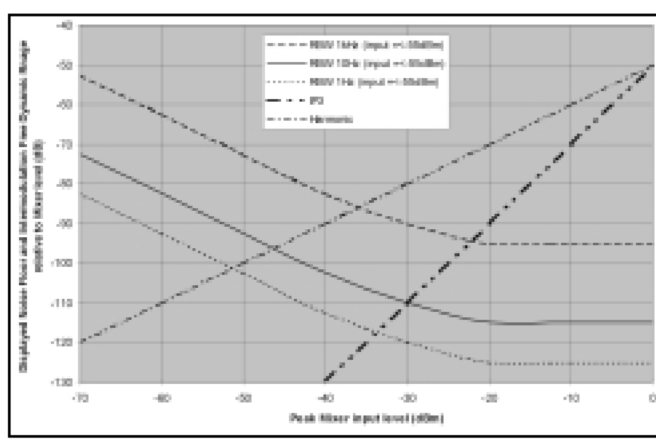

Chart 1 2309 Dymanic Range, TOI and Noise

mixer by adding attenuation will improve the intermodulation but then the noise performance is degraded and limits the measurement range unless narrower filters are used.

2309

2309 has been designed to exhibit very linear amplitude characteristics which make it ideal for undertaking high performance intermodulation measurements.

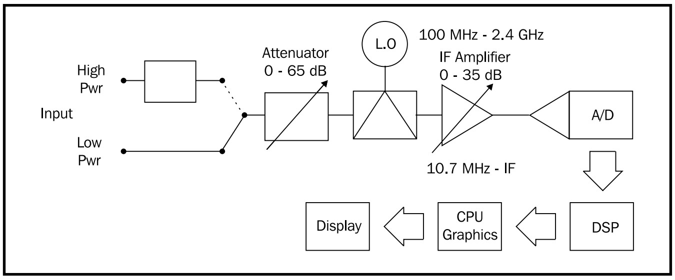

Fig 3 Architecture used in 2309

The 2309 uses a very simple down conversion scheme which avoids the complex RF chain of spectrum analyzers which can generate level errors. As a result the power accuracy of the analyzer is a remarkably good 0.5 dB up to 1 GHz and 1 dB to 2.4 GHz.

The front end frequency converter uses a very high performance mixer which has a third order intercept of typically +28 dBm. Once the signal has been down converted to 10.7 MHz it is converted to a digital format using a patented one bit band pass Sigma Delta converter. The use of a noise shaped one bit converter gives exceptional linearity performance. The combination of a highly linear front end mixer and the one bit bandpass sigma delta converter gives an overall instrument specification of better than -85 dBc for two tones input to the mixer at -26 dBm (equivalent to -20 dBm Peak Envelope Power).

The instruments relative measurement accuracy, over a large dynamic range, is superior to traditional instruments that employ largely analog IF processing or use multibit converter technology. Another benefit of the single bit converter is that intermodulation products behave in the same way as would be expected for analog devices e.g. the third order intermodulation products go down three times as fast as the fundamental. This does not happen to the same extent with multibit technology. In the same way as the use of one bit converters for CD audio systems gives the best possible performance in audio quality, the bandpass sigma delta converter gives the very best linearity for converting the IF to digital information.

One of the benefits of the 2309 architecture is that it provides excellent power linearity. The power linearity is conservatively specified at 0.01 dB/10 dB ensuring accuracy is not significantly degraded over the entire input range and that measurements can be quickly made even if the application demands the use of narrow filters.

The 2309 RF performance is enhanced by its low phase noise LO e.g. for 470 MHz input frequency the phase noise is specified to be better than -124 dBc/Hz at 50 kHz offset.

Once the information is in a digital format the signal is then processed by a DSP system and displayed as a spectral plot on the LCD panel. The use of digital rather than swept techniques ensures the data can be updated rapidly even on narrow filters.

Practical measurements

Intermodulation can be measured using a 2026 Multisource generator to drive the unit under test and a 2309 to measure the output signal. Figure 4 shows the output signal from the unit under test for a nominal output of +10 dBm on each tone, the plot being obtained via MiPlot.

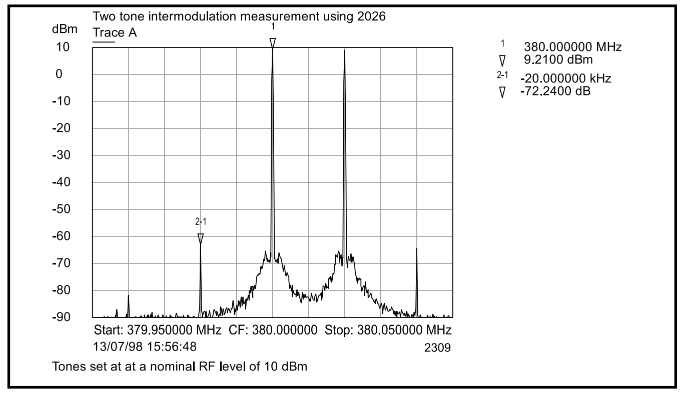

Fig 4 Two tone intermodulation using 2309

For this measurement the input level was entered to +16 dBm (corresponding to the peak envelope power of two +10 dBm tones) and the display reference level was set to +10 dBm. The Marker 1 facility was used to find the test signal frequency using the peak hold facility and the Marker 2 frequency was entered to locate the expected intermodulation frequency. Marker 2 shows a level of -72 dBm and Marker 1 a level of +9 dBm, giving a value of -81 dBc. This value is automatically displayed on the 2309 front panel by the Delta Marker facility. It can be seen that the measurement is performed with a high margin between the low level intermodulation product and the noise floor of the 2309.

The noise signals around the test tone frequencies are created by noise of the test signals and the 2309. These signals are not normally seen on spectrum analyzer since they are masked by the spectrum analyzer noise, but the dynamic range of the 2309 is such that they can be clearly seen on the display.

The measured accuracy of the intermodulation product is considerably improved compared to spectrum analyzers since the scale linearity and the absolute power accuracy of the 2309 are substantially better than that achieved by even high performance spectrum analyzers.

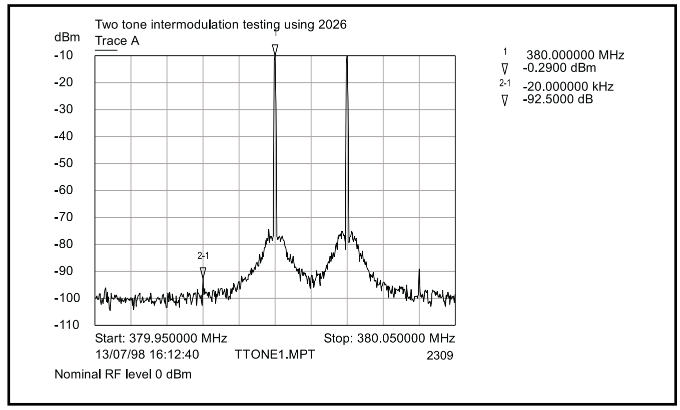

Figure 5. Two tone intermodulation with input at 0 dBm per tone.

In Figure 5 the 2309 is used to directly measure the output of 2026 at a level of 0 dBm. In this case the input level was set to

+6 dBm and the display set to a reference of -10 dBm (so the carriers are 10 dB above the display reference). The Marker was used to display the carrier power using peak hold and Marker 2 used to measure the intermodulation product at -92 dBm.

In this case the intermodulation product is close to the system noise floor, and at a far lower level than can be measured easily by a spectrum analyzer.

If even lower signal levels are required to be measured then this can be achieved by running the input mixer and converter at a lower level. In the above case if the input attenuator was increased by 10 dB the theoretical performance of 2309 will improve by 20 dB (on third order products). The noise floor of the analyzer is degraded by 10 dB and this will mask the signal. However, if the FFT BW is reduced by narrowing the span, the displayed noise is reduced allowing the 2309 to resolve the intermodulation product. The use of an FFT analyzer ensures that this can be accomplished with the minimum penalty on measurement time.

2309 Intermodulation Measurement Mode

Making intermodulation measurements of this type is greatly simplified by 2309's new intermodulation mode. This mode enables the user very quickly and easily to set up and make accurate intermodulation measurements for both amplifiers and frequency converters, and is ideally suited for repetitive testing in manufacturing or development laboratories.

The input level and tone frequencies for the measurement can be specified by the user or automatically determined by the instrument. This unique automatic feature ensures that the equipment is always optimally configured to give consistent and accurate results. Unlike other solutions, the user does not need to know anything about the measurement equipment or the test signal to decide how best to configure the test, making it ideal for use by unskilled operators. The user specifies the nominal input frequency and the instrument performs a search to find the exact frequency. The intermodulation products to be measured are then calculated. This is ideal for automated systems where some variation in signal frequency may occur and avoids complicated software search routines.

It is possible to select which intermodulation products are measured, allowing the user to measure only those products of interest in the specific application. Once defined, the measurement parameters are stored in the instrument's memory, allowing the measurement to be repeated as many times as is necessary. The instrument performs the measurement and displays the results either in table form or graphically, giving the different intermodulation products and their relative levels, as well as a pass/fail indication according to a user-defined limit. Figure 6 shows an example of the display from 2309's intermodulation application. As in figure 5, the instrument is used to measure directly the output of 2026 at a level of 0 dBm, with the input level set to +6 dBm. It can be seen that the 2309 intermodulation mode gives results consistent with those obtained using the more time-consuming analyzer application of the instrument.

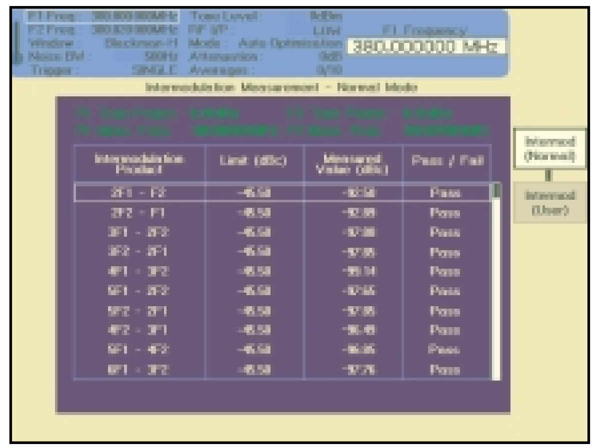

Figure 6. 2309 Intermodulation mode

A second mode allows the user to define up to 50 specific tone and product frequencies. This mode is ideal for testing multi-carrier amplifiers where intermodulation can be measured with 4 or more input tones present.

Conclusion

It has been shown that the 2309 can perform fast and accurate measurements of intermodulation which are beyond the capability of conventional swept spectrum analyzers. This makes the 2309 ideal for testing amplifiers and other devices used in modern communications systems where intermodulation is an increasingly important issue in establishing system performance.

Comparison between IFR 2309 and a range of leading Spectrum Analyzers
Summary of sources of uncertainty in level measurement

Parameter	***Brand A***	***Brand B***	***Brand C***	***IFR 2309***
Frequency Response	1.5 dB	0.5 dB	0.5 to 1.0	↑ 0.5 dB ↓
Reference Level Error	0.5 dB	0.3 to 0.7 dB	0.3 dB	
Attenuator Error	0.5 dB	0.75 dB for 65 dB step		
IF Gain Error	?	?	0.2 dB	
Linearity Error	cumulative 1.5 dB across 80 dB	cumulative 1.15 dB across 85 dB incrementally 0.4 dB per 4 dB	cumulative 1.8 dB across 80 dB	incrementally 0.01 dB/10 dB
Bandwidth Error	20%	10%	10%	Negligible
Bandwidth Switching Error	1.0 dB	0.3 dB to 0.6 dB	0.2 dB to 0.5 dB	Negligible
Input VSWR	1.3:1	1.6:1	<1.5:1	<1.1:1 to 1.43:1
Errors in Noise Measurement	2.5*dB	2.5*dB	2.5*dB	None

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