

Keysight Technologies

Enhance EMC Testing with Digital IF

Application Note



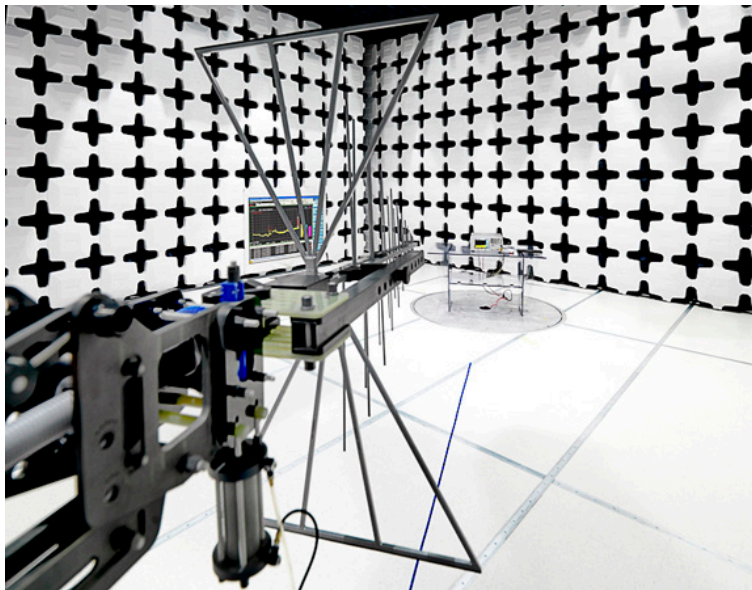
Unlocking Measurement Insights

Introduction

With today's accelerating business environment and development cycles, EMC measurement facilities that offer rapid test turnaround and high throughput, while still providing accurate and reliable measurements, will achieve greater success.

Modern EMI receivers and spectrum analyzers used for compliance and precompliance testing employ digital intermediate-frequency processing technology (digital IF) for signal analysis. Not only does digital IF boost overall instrument reliability, it enables improved amplitude accuracy, increased measurement throughput, and reduced dependence on operator experience level. These benefits result in higher efficiency and lower operating costs.

This application note will discuss the differences between analog and digital IF architectures and explain how digital IF enhances both compliance and precompliance measurement processes.



Analog IF Architecture

It is important to understand the differences between analog and digital IF architectures. Figure 1 features a basic diagram of a traditional superheterodyne receiver with an analog IF section. The RF section accepts input signals over the specified instrument frequency range and uses the frequencies generated by the local oscillator (LO) to downconvert (or mix) these input signals to an IF. Input frequency ranges can cover up to 40 GHz or higher, whereas IF frequencies tend to be hundreds of megahertz. Downconverting the input signals to a lower single frequency makes it easier and less expensive to develop circuits used to digitize and further analyze the input signals.

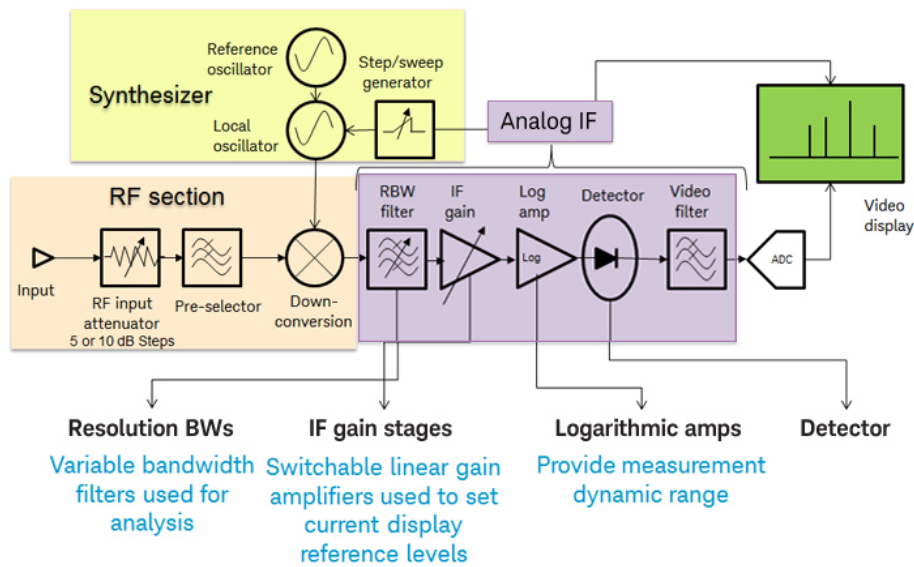


Figure 1. Superheterodyne receiver architecture with analog IF.

In an analog architecture, the IF section contains several types of analysis circuits. The resolution bandwidth (RBW) filters are a set of selectable analysis filters (typically from 10 Hz up to 1 MHz or more) that are used to observe the signal under test with different levels of frequency resolution. Narrower RBW filters are used to resolve closely-spaced input signals and wider RBW filters are used to observe wider frequency ranges more quickly. Filter bandwidths are either measured as 3 dB or 6 dB, but can also have specialized shapes such as those required by CISPR 16-1-1. Analog RBW filters are typically made with crystals or lumped components.

IF gain stages are switchable linear gain amplifiers used to adjust signal path gain in order to facilitate viewing a range of signal amplitudes. You select additional gain when decreasing reference levels to bring low-level signals higher on the display. Analog IF gain blocks tend to be in the 30 dB to 50 dB range, typically designed in selectable 10 dB steps.

Log amplifiers improve signal viewing by allowing you to observe a much higher range of signal amplitudes on the display. Logarithmically expanding the amplitudes of the lower-level signals allows you to see both small and large signals simultaneously.

For more detailed information on receiver IF circuit functionality, refer to *Keysight Technologies' Application Note 150: Spectrum Analyzer Basics*, literature number 5952-0292.

Analog IF errors

Receiver and spectrum analyzer IF circuits are calibrated using reference signals at known frequencies and amplitudes. The quality of the reference signal impacts the accuracy of the entire receiver. An IF is typically calibrated using one reference RBW and one reference gain step, and all other RBW and gain settings are calibrated relative to these references.

When adjusting receiver settings to measure signals—either manually, with software, or using an autorange capability—you are typically using different IF settings than in calibration. Changing IF settings from calibration settings contributes to amplitude measurement error. Using an analog RBW different from the calibration RBW results in switching errors, sometimes called RBW switching uncertainty. Adjusting the receiver sensitivity from the calibration sensitivity results in IF gain errors, also called reference level uncertainty.

In addition, non-ideal logarithmic performance in analog log amplifiers contributes to measurement error when signals are measured at different levels of the log display, sometimes called display scale fidelity errors. Amplitude errors increase as signals are measured farther down the log curve, away from the indicated reference level. These bandwidth switching, level switching, and log display errors are all compounded with variation in temperature.

Receivers correct for these errors to a certain degree through the use of customized calibration routines to measure errors as a function of parameter change. Receivers then apply the appropriate offsets during operation, based on the current instrument settings. While these corrections do improve receiver performance, there are limitations to the level of improvement.

You can introduce additional error if too much IF gain is applied, driving IF signals over the receiver reference level, and causing the IF circuitry to compress and distort. During both manual and computer-controlled operation, it is critical to ensure that analog IF is being used in a linear range by keeping signal levels at or below the instrument reference level.

Digital IF Architecture

Digital IF architecture reduces the measurement errors associated with analog IF circuitry. As shown in Figure 2, all analog RBWs, stepped gain, and log amplification between the final mixer and digitizer are removed. All RBWs, linear and log IF gains, and final detection are implemented digitally, after the signal has been digitized.

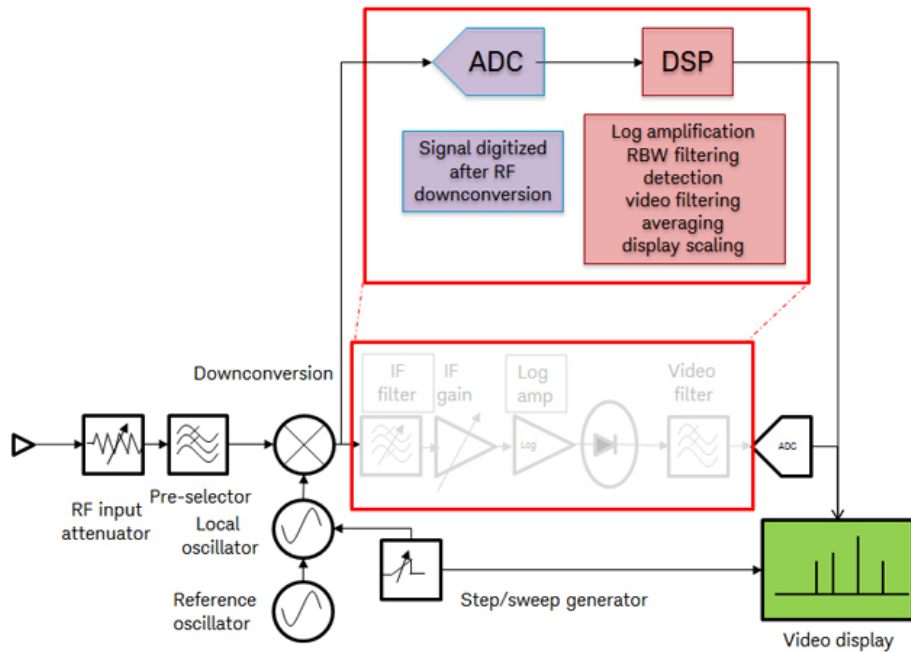


Figure 2. Digital IF architecture.

Once a signal has been digitized it is no longer at an intermediate frequency. At that point, the signal is represented by digital data values. The term "digital IF" describes the digital processing that replaces the analog IF processing found in traditional receivers and spectrum analyzers.

Digitally-implemented RBWs offer both improved switching accuracy and improved filter performance. Analog RBWs require IF gain adjustments to correct for amplitude differences between filter stages. This correction results in RBW switching uncertainty of several tenths of a decibel. Digitally implemented RBW switching uncertainty can be less than .05 dB. This is important when making compliance measurements because these measurements are made using CISPR or MIL STD bandwidths, which are different than the RBW used for calibration.

Digitally-implemented RBWs also offer improved filter performance with tighter filter shape factors. RBW shape factor, sometimes called selectivity, is typically defined as the ratio of the -60 dB filter bandwidth to the -3 dB filter bandwidth. Analog filters have shape factors in the range of 12:1, while digital IF filters have much tighter shape factors in the range of 5:1. In addition, an analog RBW filter has overall bandwidth accuracy in the 10% range while a digital RBW has an overall accuracy in the 2-3% range. The tighter shape improves the ability to resolve low-level signals closely spaced to larger signals.

Digital IF gain can provide extremely accurate reference levels. Analog IF gain steps have errors on the order of a few tenths of a decibel due to design and temperature. Digital IF gain steps are extremely accurate (0 dB error) because they are represented by a software multiplier.

Digital logarithmic correction significantly reduces measurement error associated with analog log amplifiers. The accuracy of the log correction determines the measurement error as a function of input level. In one example, errors for input signals below 27 dBuV (-80 dBm) at the input mixer are specified in an instrument with a digital IF to be as little as ± 0.15 dB over a 5 to 50 °C range. This is in comparison to the performance of an analog architecture, where the error can be greater than ± 0.85 dB over a temp range of only 20-30 °C.

Figure 3 provides an overview of the accuracy improvements digital IF offers over analog IF. The data was collected by surveying receiver and spectrum analyzer specification guides.

Amplitude uncertainty	Digital IF	Analog IF
Ref level switching	0 dB	$\leq \pm 1$ dB
RBW switching	± 0.05 dB	$\leq \pm 0.5$ dB
Display scale fidelity	± 0.15 dB	$\leq \pm 0.85$ dB

Figure 3. Comparison of amplitude uncertainties associated with digital and analog IF architectures.

Benefits of Digital IF

The improved performance provided by digital IF architecture offers significant benefits to an EMC test facility.

Improved instrument amplitude accuracy

The enhanced accuracy provided by digital IF results in more precise amplitude specifications for receivers and spectrum analyzers. Not only can you make more accurate measurements, you benefit from this improved accuracy over a broader range of instrument settings. As mentioned earlier, the digitally-implemented log correction provides increased measurement accuracy for very low level signals. This is important in an EMC measurement environment because low signal levels are encountered on a regular basis when making compliance measurements.

Improved measurement throughput

One measurement technique EMC laboratories have adopted to minimize the effects of errors associated with analog IF log amplification is to always bring the peak signal to the reference level prior to final quasi-peak or average detector measurement. This technique brings the IF level to the top of the current reference level setting, which eliminates the log display error. While effective, this measurement technique takes time because it has to be done on every signal. Automation software can reduce the time impact, but the measurements must still be done on every signal. The total time savings is a function of the number of signals being measured.

The enhanced accuracy of the digitally-implemented log correction minimizes the need to adjust each signal to the measurement reference level prior to final measurement. This is a considerable time savings when testing devices with a significant number of emissions.

Reduced dependence on operator experience

While many aspects of compliance testing have been automated, final measurements can still require manual interaction to quantify signal amplitude variation rate (as per CISPR), fine-tune to maximize signals, and adjust measuring receivers to ensure amplitude accuracy—all requiring a highly-trained operator.

Correct operation of an EMI compliance receiver can be a challenging task without the right level of experience. Adjusting the receiver to make a measurement with the highest level of accuracy possible requires significant training and skill. Digital IF technology makes it easier for a less experienced operator to make measurements that meet commercial and military amplitude requirements.

For example, an inexperienced operator is more likely to accidentally overdrive the instrument while making a measurement with analog IF technology, resulting in incorrect amplitude values due to instrument compression and distortion. Digital IF doesn't require stepped IF gains, so the opportunity for overload is minimized when signals are below the maximum allowable input level for linear operation. Figure 4 illustrates this example. Figure 4a shows a display of a 107 dBuV (0 dBm) CW signal, while Figure 4b shows that same signal displayed with the reference signal shifted by 50 dB. Note that the indicated marker values are virtually identical—under identical conditions, a receiver or spectrum analyzer with an analog IF would be severely distorted and the marker values would be significantly different.

Figure 4. Digital IF reduces the opportunity for instrument overload.

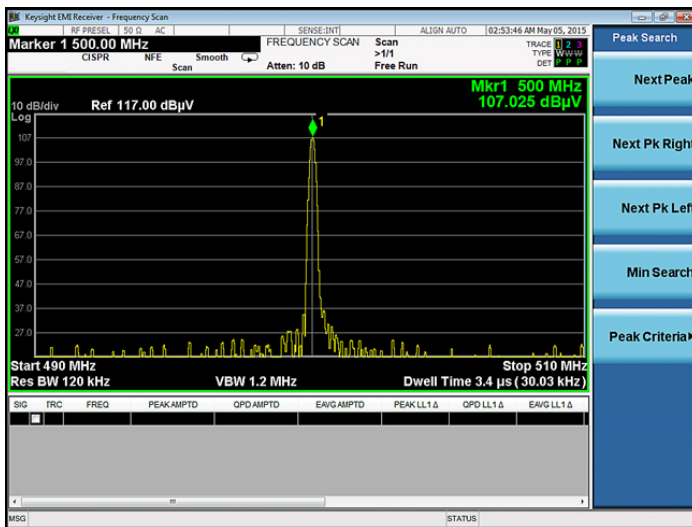


Figure 4a. Test signal near the reference level. Compare the marker value to Figure 4b.

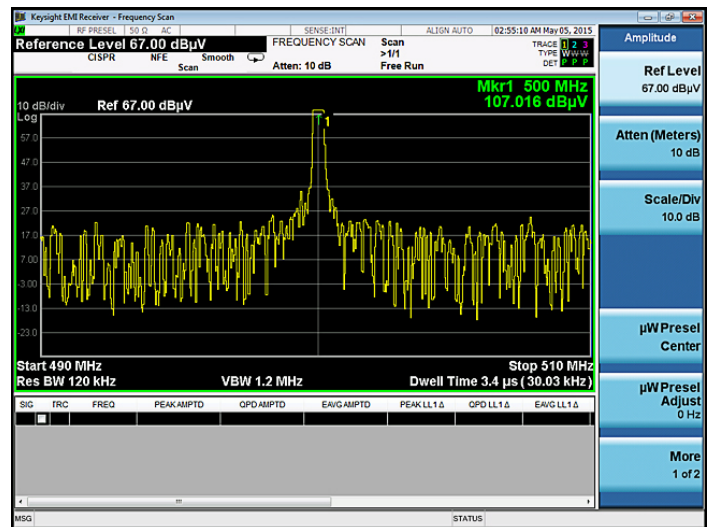


Figure 4b. Same test signal, 50 dB above the reference level with a virtually identical marker value to Figure 4a.

Reducing dependency on operator skill allows newer personnel to contribute more quickly and relieves lab manager concerns about measurement accuracy. It also minimizes the impact that training time has on the availability of the more experienced lab members.

Improved ability to identify low-level emissions in a high-ambient environment

When making compliance or precompliance emissions measurements on an open site, it can be difficult to resolve low-level emissions in the presence of high-level ambient signals, such as commercial radio and television broadcasts, cellular transmissions, and public safety communications.

The tighter shape factors offered by digital IF resolution bandwidths allow you to resolve and identify emissions that are located closer to ambient signals. Accurately identifying and measuring these signals reduces the chance that hidden signals will cause a surprise failure at a final measurement in a shielded environment. This capability is very important for precompliance measurements, which are typically made in an open-air environment.

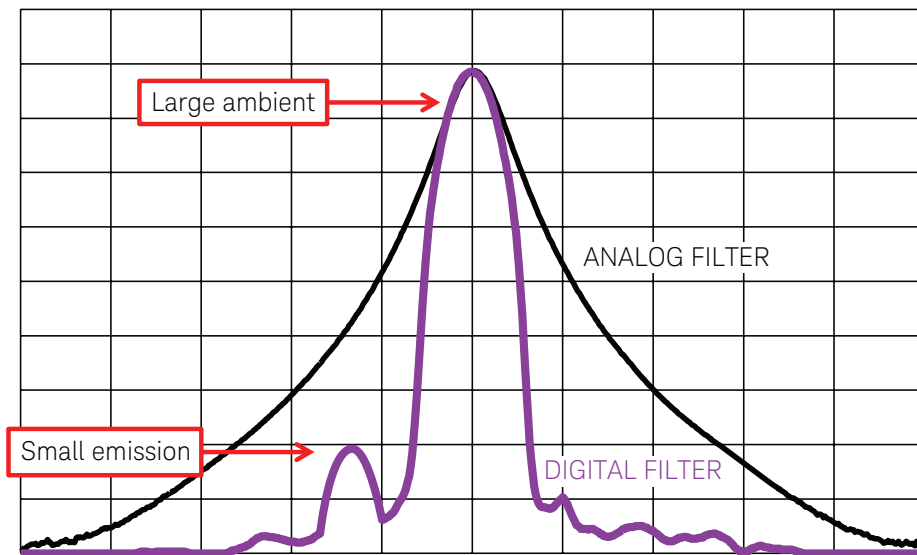


Figure 5. Digital IF RBWs offer greater selectivity than analog RBWs, enhancing emission detection in the presence of large ambient signals.

Conclusion

An all-digital IF architecture provides significant improvements in test throughput, measurement accuracy, and required operator training. You can utilize these advantages to increase the efficiency of your facilities, resulting in lower operating costs and greater return on your measurement assets.



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