PRONGHORN SOLUTIONS

MULTI-TONE TESTING OF MICROWAVE AND RF COMPONENTS

Why is multitone signal generation important?

It is an effective means of characterizing the linearity of amplifier and other components in communication systems.
It can also be used for radiated immunity testing.

How can multiple test tones be generated?

Simplest (and most expensive) approach may be to combine the outputs of N number of separate signal generators through an N-way power divider.
Digital sources, such as a direct digital synthesizer (DDS), can also be used to generate multiple tones, although at a more limited total bandwidth and with less output power than separate signal generators.
Similarly, a vector signal generator, which is typically based on a DDS or arbitrary waveform generator, can also produce outputs with multiple tones.

Considerations for a multitone test generator.

How many tones are needed for testing?
What is the maximum bandwidth, or separation between signals, available?
What it the output power of the separate tones?
Amplitude range?
Frequency range?
Tuning resolution?
What is the spectral purity (spurious, phase noise) of the test generator?
What are the modulation capabilities?
What is its power consumption—per tone and total?
What is the size and weight of the total generator?
How do the costs of the different generator approaches compare?

How is the generator controlled?
How difficult is it to set up a multitone output?
Type of software it can be used with?
Is it compatible with all the standards, including MATLAB and LabVIEW?
What about with Agilent Vee?

MULTI-TONE TESTING OF RF AND MICROWAVE COMPONENTS

INTRODUCTION

As Communications systems get more complex and the frequency spectrum gets more and more crowded, the nonlinearities of active (and sometimes even passive) devices and circuits and the resultant intermodulation products become more and more important to test, verify, and often to certify. Two-tone testing and Multi-tone testing, that in the past was done at the design verification phase and after that only on a sampled basis, now often need to be measured on every amplifier or other active device or system that a manufacturer ships. In testing broadband devices that cover an octave or more, this testing may have to be done not only on a swept basis with constant frequency differential two tones, but also with a constant center frequency and diverging tones that cover the band. Often such testing cannot be done with a single signal source, even a Vector Signal Generator with complex multitone generation capabilities. Radiated Immunity Testing is another critical component of this with systems such as the MT06000 system from Amplifier Research [1] supplying test systems for this specific purpose.

It has also been observed [2] that the relative phase between the multiple tones can have significant impact on the measured intermodulation distortion. This implies that the system designer of a broadband system may not only have to measure the distortion based on frequency differential, but also on phase differential – which also means that such test may need to be done over temperature rather than only at room temperature. Not many studies have been made with amplitude differentials, but with non-linear devices, it is easy to prove that amplitude differentials can cause problems for the lower amplitude signal in the presence of a higher amplitude signal.

Moving forward, in fields as diverse as 4G, LTE, MIMO, SATCOM, and EW/ECM systems, multi-tone testing in a Production Test basis rather than a Design Verification basis is going to be important enough to be mandated or specified. This means that a Cost Effective and Production Effective system is needed. Many different solutions have been proposed – from moving the testing effectively to time domain by Envelope Testing [3] or by having a Built In Test (BIT) strategy [4].

This White Paper offers a Cost Effective and Production Test Meaningful solution to this issue. It is based upon building a Test Frame that provides only what most (>90%) of systems need in terms of Frequency Resolution and Accuracy, easy Configurability, and absolute control over the frequency and phase (reference) differential between test frequencies, and indeed between amplitude differentials.

MULTITONE TEST SIGNAL GENERATION ALTERNATIVES

In the past, generating Multitone signals meant for test purposes meant racking a number of microwave or RF signal generators together, combining their outputs and using this combined signal as the input to the device under test [5] as shown in Figure 1.

This was expensive. As a result, Multitone tests were often done only to prove a design, assuming or building in enough margin that production tests were not considered necessary. Even the one dB compression test on semiconductor devices was not done on a chip basis but really on a wafer basis.

A Multitone signal can be generated as a time function of a combination of sinusoidal signals. Thus if we consider a combination of three sinusoidal signals given by

$$V_i(t) = V_1 \sin(\omega_1 t + \phi_1) + V_2 \sin(\omega_2 t + \phi_2) + V_3 \sin(\omega_3 t + \phi_3)$$

Where the ω's are the $2\pi f$ frequencies and the ϕ's are the related phases, $V_i(t)$ is a function of time and periodic, then the result can be considered a function of time, and this function, when it drives the device under test (DUT), will produce all the components that such a signal would create when driving a nonlinear device. The combination of the harmonics of each frequency and their addition and subtraction with all other harmonics can be mathematically described.

If signal such as Vi(t) can be created as a function of time with any combination of $V_{1,\ 2,\ 3}$, etc, and $\omega_{1,\ 2,\ 3}$, etc, and $\phi_{1,\ 2,\ 3}$ etc., this would be ideal. But with today's technology, even with the best commercially available DDS synthesis techniques available this is only reliably possible at frequencies below 2 GHz. With today's systems that go beyond 18 GHz to 30 GHz and beyond, this is not a realistic alternative.

A second alternative is to use a vector signal generator. A VSG can effectively create, using modulation techniques, a multi-tone signal. However, it has two very significant drawbacks. Since it depends upon modulation, the effective frequency between signals can only be less than 100 MHz. Further, there is no way to control the amplitude of the the signals V_1, V_2, and V_3, not to mention the relative phases. And the cost is not insignificant, and needs a dedicated test system with dedicated software.

A third alternative exists, which consists of going back to the original simple architecture of a number of synthesizers, all driven from a single reference source, all individually programmable in relation to amplitude and phase, each of which is very low cost due to the simplicity of its architecture, its low power consumption, but with the elimination of the limitation of the time domain approach described first and the vector signal approach described second. This is what we propose and will describe in the rest of this white paper.

MULTITONE SIGNAL GENERATOR CONSIDERATIONS

The basic requirements to be defined in Multitone testing are

1. Number of Tones or Signals
2. Frequency separation – fixed or variable
3. Bandwidth or sweep requirements
4. Amplitude and Frequency Range
5. Amplitude and Frequency Resolution
6. Spectral Purity
7. Modulation Capabilities
8. Power Consumption
9. Size and Weight
10. Cost

When these are considered together, it is clear that an arbitrary set of signals would be very difficult if not impossible to simulate with DDS except at very low frequencies. A VSG may be able to satisfy items 2, 3, 4, and 5, within a small range. Modulation capabilities are of not concern in most test cases. And, without a doubt, the first two approaches, DDS, and VSG, will require dedicated pieces of equipment requiring significant size, weight, power consumption and cost needs.

On the other hand, the PHS-6000, which is a combination of the desired number of independently programmable PHS-5000 low cost synthesizers with 10 KHz resolution to 9 GHz, the ability to be run off the same reference, and with programmable amplitudes in each of the signals and programmable phase shifts, each consuming less than 5 watts, is a lower cost, lower risk, re-definable, easy to reprogram alternative with vastly superior capabilities in frequency separation and programmability, Power separation and programmability, with multiple tones.

The cost of a 10 synthesizer PHS-6000 would be less than the alternatives, with no limitations except in the frequency resolution area where the PHS-6000 would offer 10 KHz .

HARDWARE DESCRIPTION

The PHS-6000 consists of the required number of PHS-5000 units with external power combiners and control circuits (e.g. phase shifters if needed), with all these running off a common 10 MHz reference. These units run off 8.4 Volts DC, each drawing less than 450 mA (power consumption <4 Watts per PHS-5000), with full separation programming and tracking frequency sweep programming as well as power level programming.

SOFTWARE DESCRIPTION

The PHS 6000 is programmed using a basic Visual Studio base, and includes an indipendent GUI as well as the capability to address each individual synthesizer using IVI RF SigGen interface, which makes it capable of VISA and GPIB programming. It will also be capable of MATLAB and Labview programming. A PXI compatible software interface is being developed with hardware compatibility to follow.

CONCLUSION

Multitone testing requirements will only get more general, more diverse, and more a requirement in the future. We believe the approach we offer is one that affords the best price/performance/longevity objective.