Letters to the Editor

A Low Budget Vector Network Analyzer for AF to UHF (Mar/Apr 2007)

Dear Doug,

Some time ago you asked me to write some additional explanations on the alias concept for my vector network analyzer, described in the Mar/Apr 2007 issue of *QEX*. Here is some additional text to go with that article.

— *73, Dr Thomas C. Baier, DG8SAQ, University of Applied Sciences, Prittwitzstrasse 10, 89075 Ulm, Germany*; **baier@hs-ulm.de**

Using Unfiltered DDS-Signals for Measuring Frequency Responses

The *QEX* article on my unique direct digital synthesizer (DDS) and PC based vector network analyzer (VNWA) design has invoked quite a few questions on how the DDS output spectra are processed in order to obtain accurate measurement results.[1] Since this was touched on only briefly in the article, a more detailed discussion is given here. The simple way my VNWA handles DDS aliasing frequencies (also called image frequencies) makes it unique.

Figure 1 shows the fundamental setup that most modern network analyzers, as well as my VNWA, use to measure the frequency response of a device under test (DUT). An RF source delivers power to the DUT whose output signal is mixed down by an LO to an IF that is filtered and analyzed. The most common realization of this setup is by using spectrally pure sine wave oscillators for both the RF and LO. This doesn't have to be the case, however. A measurement of the DUT transfer function is also possible by using a wideband noise source for the RF signal and a sine wave for the LO signal. In this case, all frequencies are present at the output of the DUT, but the single frequency LO, in combination with the IF-filter, make sure that only the desired piece of the DUT output spectrum is analyzed by the signal analyzer, as in any heterodyne receiver.

In my VNWA design, DDS oscillators are used for the RF and LO generation. The IF filter is realized through the limited frequency response of the PC soundcard used for signal analysis (typically 10 Hz to 20 kHz transmission band) in combination with digital filtering by the PC software. Due to the sampling principle, the DDS signal sources do not deliver pure sine waves, but they do produce a step function with a predictable spectrum, which is shown here in Figure 2. (This is the same as Figure 3 in the original article.) My VNWA design does not use any kind of filtering of the DDS signals. The VNWA does *not* contain any RF filters. The only frequency selective part is the sound card used to detect the IF signals.

As already mentioned, the RF signal of a network analyzer does not necessarily have to be a pure sine wave. Care has to be taken though, that only the desired radio frequency is mixed into the IF bandwidth with the LO signal. If this can be guaranteed by tricky frequency management like in the VNWA design under discussion, then the LO signal need not be a pure sine wave.

Figure 3 shows an example of how this can be achieved by running the RF DDS and LO DDS on unequal clock frequencies. It shows the output spectra of the RF DDS (solid) and LO DDS (dashed) dependent on the tuned RF frequency at which the measurement is intended to be performed. At any particular tuned RF frequency (examples are indicated with dashed-dotted vertical lines), there are a multitude of RF and LO spectral components. Any two of these can generate an IF in the mixer. A few IFs are indicated in Figure 3 by arrows. Note that only the desired pair of RF and LO frequencies produce the desired IF, since only these have the desired vertical dis-

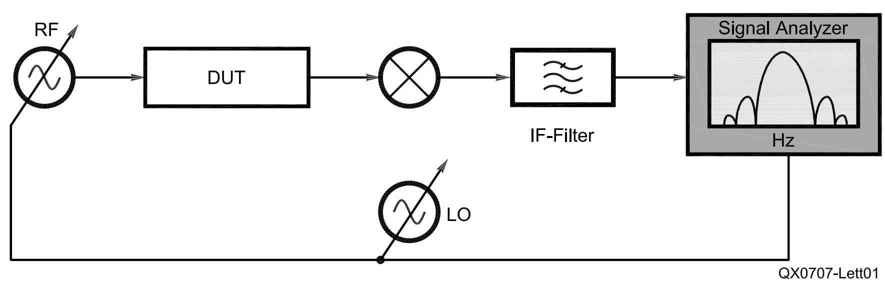

Figure 1 — Basic setup of a network analyzer.

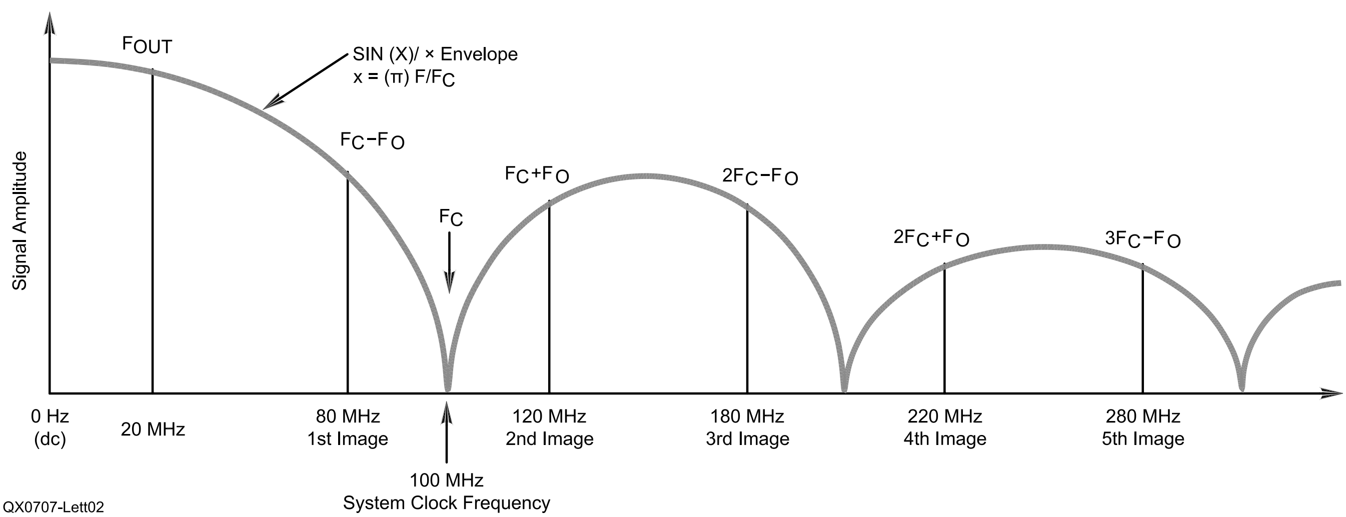

Figure 2 — Unfiltered output spectrum of a DDS clocked with 100 MHz (courtesy of Analog Devices).

Table 1
Possible RF and LO Frequencies to Give the Desired IF

Example 1	*Desired Frequency*	*Tuning Word*	*Fund Freq*	*1st Alias*	*2nd Alias*	*3rd Alias*	*4th Alias*	*5th Alias*
RF DDS	20	477218588	20	160	200	340	380	520
LO DDS	40	1010580540	40	130	210	300	380	470
IF = |RF – LO|			**20**	30	10	40	0	50

Table 2
Possible RF and LO Frequencies to Give the Desired IF

Example 2	*Desired Frequency*	*Tuning Word*	*Fund Freq*	*1st Alias*	*2nd Alias*	*3rd Alias*	*4th Alias*	*5th Alias*
RF DDS	120	2863311530	60	120	240	300	420	480
LO DDS	140	3537031890	30	140	200	310	370	480
IF = |RF – LO|			30	**20**	40	10	50	0

Table 3

Example 3	*Desired Frequency*	*Tuning Word*	*Fund Freq*	*1st Alias*	*2nd Alias*	*3rd Alias*	*4th Alias*	*5th Alias*
RF DDS	300	2863311530	60	120	240	300	420	480
LO DDS	320	3789677025	20	150	190	320	360	490
IF = |RF-LO|			40	30	50	**20**	60	10
Example 4	*Desired Frequency*	*Tuning Word*	*Fund Freq*	*1st Alias*	*2nd Alias*	*3rd Alias*	*4th Alias*	*5th Alias*
RF DDS	370	238609294	10	170	190	350	370	530
LO DDS	390	1263225675	50	120	220	290	390	460
IF = |RF-LO|			40	50	30	60	**20**	70

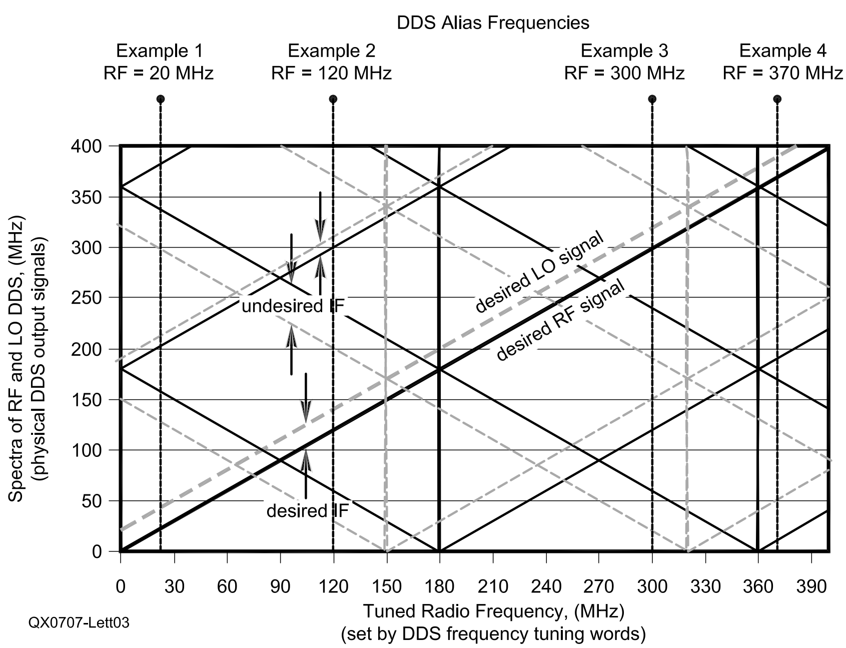

Figure 3 — LO and RF DDS output spectra versus tuned RF. The solid traces are RF signals and the dashed traces are LO signals. The arrows indicate some possible RF-LO-mixing products. The examples are described in more detail in Tables 1-3. For better visibility, the RF clock frequency is 180 MHz, the LO clock frequency is 170 MHz and the desired IF is 20 MHz.

tance in the graph. All other pairings produce different IFs. This works out only due to the fact that the RF and LO DDS run on different clock frequencies. If they ran on one and the same clock frequency, every RF alias would have a matching LO alias to produce the very same IF, thus making a spectral separation of the aliases impossible.

Another question I was asked was how to set the DDS 32-bit tuning words to produce the desired alias frequencies. This is best illustrated with a few numerical examples, which are indicated in Figure 3.

The basis for calculating the tuning words is the following formula from the DDS data sheet.

$$n = \frac{f}{f_{clock}} \cdot 2^{32}$$

Example 1: Assume we want to measure a transmission of our DUT at 20 MHz. Thus the RF DDS needs to generate 20 MHz, the LO DDS needs to generate 20 MHz + IF = 40 MHz. With the above formula, the 32 bit tuning words can simply be calculated to yield the values in Table 1. Remember that the RF clock frequency is 180 MHz, while the LO clock frequency is 170 MHz in our example design. With these tuning words, the DDS sources produce the desired 20 MHz RF and 40 MHz LO respectively. But they also produce alias frequencies; for example the first alias of the RF DDS is 180 MHz – 20 MHz = 160 MHz. The second alias of the LO DDS is 170 MHz + 40 MHz = 210 MHz. Comparing the aliases in Table 1, there is obviously only one pairing that yields a 20 MHz IF when mixed. Note that the table does not show all possible mixing products of the shown aliases, but only those in the vicinity of the desired IF.

Usually a DDS is used to produce less than 50% of its clock frequency. Table 2 displays example 2 where this is not the case.

The DDS tuning words can still be calculated with the above formula. The fundamental DDS frequencies are not the desired output frequencies, however. But the first aliases turn out to be exactly the wanted signals. Also here, only the desired signal pair mixes to 20 MHz IF.

Examples 3 and 4 in Table 3 demonstrate what happens when the DDS tuning words calculated with the above formula exceed the word lengths of 32 bits. In this case, the leading bits beyond bit number 32 are simply ignored. Thus, one arrives at 32 bit tuning words again. By doing this, it turns out that the DDS sources are set such that aliases produce exactly the desired frequencies. Again, only the desired pairs produce the correct IF of 20 MHz.

Finally, I would like to point to a very nice article by Sam Wetterlin, who has illustrated how, by this idea and by making the clock frequencies variable, it is possible to construct a VNWA that covers a wide frequency range without frequency gaps.[2]

A very small VNWA kit, which I hope will cover a frequency range up to 1 GHz is currently under development. For information on availability and pricing please visit the Web site listed in Note 1.

Thanks to Mike Alferman, WA2NAS, for straightening out my manuscript.

Notes

[1]Professor Dr Thomas C. Baier, DG8SAQ, "A Low Budget Vector Network Analyzer for AF to UHF," *QEX*, Mar/Apr 2007, ARRL, see also **www.mydarc.de/DG8SAQ/VNWA/index.shtml**

[2]Sam Wetterlin, "Using DDS Aliases to Extend the Frequency Range," **www.wetterlin.org/sam/AD9952/MultipleClockAliases.pdf**

High Speed Multi-Media Working Group

Dear Doug,

Thank you most kindly, sir, for your warm comments about the accomplishments of the League's HSMM Working Group (WG) in your editorial in the May/June 2007 issue of *QEX*. The WG's dedication and efforts are ongoing, as reflected in many radio experimenters projects.

We are particularly proud of the excellent article in your same issue of *QEX* by WG member Roderick D. Mitchell, KL1Y, "The Integration of Amateur Radio and 802.11" and your excellent presentation thereof.

Thank you so very much for all your outstanding efforts to keep Amateur radio on the cutting edge of modern radio and electronics technology.

— Very 73, John Champa, NCE (K8OCL), Wireless Systems Engineer, Rockwell Collins, Former Chairman, HSMM WG, 17850 Sunmeadow Dr, Apt 2303, Dallas, TX 75252; **k8ocl@hotmail.com**

Hi John,

Thanks also for all the work you and the all the members of the Working Group have done, and continue to do. I agree that Rod Mitchell's article is an interesting report on some of that work.

What else do you have to report? *QEX* stands ready to report on the WG's efforts. If you or anyone else on your group would like to write for *QEX*, please submit your articles.

— 73, Larry Wolfgang, WR1B, QEX *Managing Editor;* **lwolfgang@arrl.org**

Automatic Noise Figure Meter (May/June 2007)

The subject article is a good example of how a measurement problem can be solved by a little thought, without needing to buy or borrow expensive commercial equipment. Twenty or so years ago, I was faced with how to make NF measurements on some VHF and UHF very low noise amplifiers, but my university research lab was not equipped with a noise figure meter.

The solution was a calibrated noise source, a broadband amplifier, a tunable band pass filter and a power meter to measure the noise with the noise source off and then on. All these items were available in my lab. The NF was calculated from the Y factor given by the power meter. I never thought my idea was new, but I was surprised to find that the vendor for the low noise amplifiers had never thought of using my procedure. He was surprised to see that my measurements were quite accurate also.

Good article!

— 73, John H. Bordelon, PhD, K4JIU, 1690 Hampton Oaks Bend, Marietta, GA 30066-4451; **k4jiu@arrl.net**

Hi John,

Thanks for the compliments. We're glad you liked this article.

— 73, Larry, WR1B.

Components Cross Reference

Dear Sir,

I have some data to help fill a hole in the HP cross reference to JEDEC or 300-hpxref.pdf. HP part number 1858-0054 is an exact match for an Intersil (RCA) CA3096 transistor array.

We found this part in an Agilent service manual. By "we" I refer to a group to which I belong that promotes classic computer stuff.

I'm also a proud ARRL member. Thanks for helping us pass along this information!

— 73, Steven Canning, PO Box 1682, La Mirada, CA 90638; **cannings@earthlink.net**

On the Crossed-Field Antenna Performance, Parts 1 and 2 (Jan/Feb and Mar/Apr 2007)

Dear Doug,

I feel the article on the Crossed-Field Antenna was far below the technical level set up to this point by *QEX*.

I know there is a great deal of discussion about the theory, but most knowledgeable antenna experts do not give this antenna any real credibility. In fact, the credit seems to go to the feed line.

I always look forward to reading *QEX* and enjoy the level of articles presented. This one just seemed out of place. It would have been better placed in the April issue.

— Doug Millar, K6JEY, 2791 Cedar Ave, Long Beach, CA 90806; **dougnhelen@moonlink.net**

Hello, Doug.

I'm dismayed to see another IEEE article reprint that takes eight editorial pages in *QEX*. I have written previously to express my disappointment at reprinting verbatim articles that appeared elsewhere. Post such a reprinted article on the ARRL Web site, if you wish, but I pay for a *QEX* subscription to learn about new things of interest to communication experimenters. I have no interest in wading through dense mathematics presented previously in a professional-society publication. I doubt most other "experimenters" will either. To make matters worse, this article's second part will take more editorial pages in a future *QEX*. This isn't the type of information I signed up to receive in the pages of *QEX*, so I intend to let my *QEX* subscription lapse.

— Jon Titus, KZ1G, 5526 West 13400 South, Suite 105, Herriman, UT 84096; **jontitus@comcast.net**

Gentlemen,

We are sorry that you did not enjoy the crossed field antenna article. Direct reprints of previously published, readily available articles have been a rare occurrence in the pages of *QEX*. This research seemed to be worth sharing with *QEX* readers.

I hope you will consider sharing some of your own work with our readers. *QEX* is dedicated to sharing experimental work and ideas about a wide array of communications topics.

Jon, I hope you will also reconsider your decision to allow your subscription to lapse based on this one article. I hope you have found many other articles of interest and that you would look forward to reading more excellent articles in the future!
— 73, Larry, WR1B.

ARES Communications Protocol

Editor,

I am interested in investigating an improved communications and message traffic handling system for use in ARES deployment situations. I am both an Amateur Radio operator and a computer/information scientist and my experiences with existing UHF based communications systems has shown the difficulties inherent in voice-based, simplex communications and message handling.

The situation I am attempting to address is how to avoid overlapping transmissions when operating in a simplex mode (we are training for a worst-case situation with no repeater availability). The difficulty occurs when, in simplex mode, you have a network control station and remote stations, and the remote stations cannot hear each other but can communicate with the control station. The reality is that too often we have "collisions" when remote stations transmit simultaneously, and in emergencies this delay and or loss of successful communication could be fatal. One solution is for remote stations to call and wait for permission to transmit; another is a roll-call protocol. For standard voice communications, the call and wait protocol makes good sense and works well with disciplined operators. As we move to digital communications, however, there are better ways to avoid message collisions and the automated roll-call (poll-response) initiated by the control station is the one I am investigating. Packet or even character format communications would appear to be readily available. The missing pieces in this system relate to the network level protocol to control communications.

The AGW suite of software and the AX25 Connected mode protocol appear to have almost all of the features I am seeking, although not exactly in the way I want (poll response).

Any information that your readership could provide on others who are also looking into, or working on this same or related communications protocol would be greatly appreciated.
— J.J. Hayden, KN4SH, 45 Cory Ct, Covington, GA 30016; **jjhaydeniii@earthlink.net**

Antenna Options — NVIS Antennas for Special Needs (May/June 2007)

LB's article on discussing wide band NVIS antennas shows so clearly the obsession many have with antenna matching. Here is an antenna (terminated V) that has at least four dB more loss than an unterminated one, favored by some purely because it matches the source better. Take the unterminated version and put a 3 dB pad in front of it and the amplifier will be happy, and more RF will reach the destination! Obviously there is more to life than SWR.

I would call into question one statement, though. "Since the … transmitter [scans] so rapidly, it does not have time for the delays associated with changing matching networks …". There may be situations where this is true, but in general, it is very possible to design tunable matching networks using PIN diodes that can respond in microsecond time frames. For HF, it is more challenging because PIN diodes that can work down to 3 MHz are harder to come by, and will take longer to change state, but it is not impossible. High speed PIN diode devices are not likely to dominate Amateur practices anytime soon because of cost and other factors. For military applications, however, such devices provide an alternative to wideband NVIS antennas.

One of my clients manufactures tunable aircraft antennas that cover 30 to 500 MHz. This is a blade less than a foot in any dimension! It is used with military hopping radios and can settle on a new operating frequency in 10 µs. The radio sends the new frequency to the antenna as a digital word and the microprocessor inside selects the proper combination of PIN diodes to resonate this little blade to that frequency.
— Wilton Helm, WT6C, Embedded System Resources, 320 Old Y Rd, Golden, CO 80401; **whelm@compuserve.com**

Hi Wilton,

I agree that in principle it is possible to reduce the transition time within the matching networks to the very short interval that you indicate.

Unfortunately, such tuning units are not presently available — to my knowledge — at the frequencies indicated for amateur and related NVIS services at the power levels typically used and at a price that most amateurs can pay. That is the context within which my notes were applicable.

I also agree that in principle SWR is certainly not everything, but with typical amateur transceivers the output impedance is fixed within a very small range with foldback circuits to limit final amplifier power when the SWR indication is greater than a certain threshold. Hence, the amateur need to match is a practical matter, not a theoretical one.

An alternative to high-speed matching is, of course, slower speed ALE processing, so that the speed of channel scanning matches the speed of available automatic tuner switching for ATUs that already exist or that can be developed to fit amateur budgets. Military and other services that need burst transmissions to keep channels and data secure may require the very high speed of the latest ALE processors, but the emergency services rendered by radio amateurs and many of the agencies involved in similar services do not need such security — only efficiency.
— 73, LB Cebik, W4RNL, 1434 High Mesa Dr, Knoxville, TN 37938; **Cebik@cebik.com**