Number 44 on your Feedback card

VHF and Above Operation

C. L. Houghton WB6IGP
San Diego Microwave Group
6345 Badger Lake Ave.
San Diego CA 92119
[clhough@pacbell.net]

Noise and Its Amateur Implications

Noise in its broadest terms is something we are all familiar with. Noise from mechanical devices, electrical devices, and all sorts of things all add up to make noise a part of our everyday life. Noise from the dog at 3 a.m., noise even from our grandchildren at play can really make you wish you could turn down their amplifier and have some peace and quiet. While turning down the noise source is a good idea, it's not possible in the modern world (electronically speaking) that we live in. Unfortunately, we must confront head-on the contributions of noise produced by all the technology that we have become accustomed to using.

The real fight for survival is inside our equipment and in the design of devices to counter this noise problem. While I don't want to go into noise blankers and other receiver noise circuits, I do want to take a slightly different tack and go into identifying the noise sensitivity of receiving systems and preamps in general. What is interesting to note is that all receivers contribute noise to the receiving system, with some better (less noise) than others. This internal noise product is what we are examining in receiving systems, be it a preamp or receiver. We want to identify just what inherent noise each component amplifier part is capable of supporting. Eliminating noise completely is not possible, as all devices make or generate noise as a function of current flow. While other devices try to selectively sort through this noise and pull out real signals, adjusting first stage amplifiers for minimum noise figure produces the best results.

That's the real topic for radio amateurs — pulling very weak signals out of the gobbledygook we all refer to as "noise." I am sure if we listen to noise long enough we can even make a contact with some rare callsign. Humor aside, we all have listened for long times to find weak signals, both real and imaginary, trying to fish a contact out of the noise while searching up and down the band adjusting our antenna and peaking our receiver for best performance.

Noise is what we hear when we unsquelch our handhelds or listen to a high frequency receiver — it's all noise, at least until a real signal hopefully comes roaring through. We can take a signal generator and examine almost any receiver to find out its minimum sensitivity in microvolts and how much gain it gives, but this does not give a true picture of the system performance. What is needed is a measurement of noise figure.

Noise figure is a ratio used to rate each system or component amplifier of a system. The lower the noise figure number you can obtain, the better your system will be able to pick a very weak signal out of the external noise. There is, however, a requirement that the weak signal you expect to find is higher in level than the ambient or external noise. In other words, if the signal you want is on even par with elevators, generators, and automobile ignition systems (to mention a few contributing noise sources), there is not much that will allow you to receive a workable signal. Even the neighbor's Mixmaster can wipe you out with noise and make your receiver unworkable, at least until the cake mix is finished.

Remembering back to my HF days as a Novice, I was always adding on to my HF receivers' adjuncts to improve sensitivity and performance without having test equipment to evaluate just what improvements my system was capable of detecting. In those early days I did not realize that the HF receivers, hot as they were, did not need much improvement as far as noise figure was concerned, as the external noise was so great there was little that could be done to improve the receiver to overcome it. To be able to copy signals that are below this threshold ("signals below the external noise floor"), other special techniques are required.

My first noise meter was a simple diode noise source serial #2, a prototype found at a local surplus store. It was used to evaluate military receivers from 1 to 400 MHz. Or rather, instead of testing them, it was supposed to be used first when the receiver was new to make a noise reference meter reading and record it for maintenance checks. It was then used to test all receivers of a specific type, and at a specific frequency have a meter reading of, say, 5–7 on the reference scale. If it went to a larger number, the receiver was getting numb and needed service. What a neat device for a quick evaluation confidence check of a system receiver, as it did not require extensive calibration. (This was for AM, CW, and SSB receivers only. It will not work for FM.)

Later on, the pursuit for better noise figure (without the capability of measuring it) was hot underway. Operation on 2 meters and above was all the rage. First came the Gonset Communicator (a tube radio) and its RF amp, a 6BQ7 with a NF of 7 dB or so at 2 meters. New improvements came on, as the Nuvistor touted then as sort of a solid state miniature tube (the 6CW4) with a NF of about 3 to 4 dB. To really get the best noise figure at this time, the ultimate at 2 meters was the historic Western Electric 416B gold-plated lighthouse tube. Noise figures in the 1 dB range were at hand, but at a price — that being a supply of pressurized air to prevent the glass seals from cracking from tube heat. Not to mention a high voltage DC power supply for the 416B and its $50 price tag.

Then entered the solid state transistors from Texas Instruments called the TIXM05 and its family of devices that equaled the 416's 1 dB NF and was solid state and about

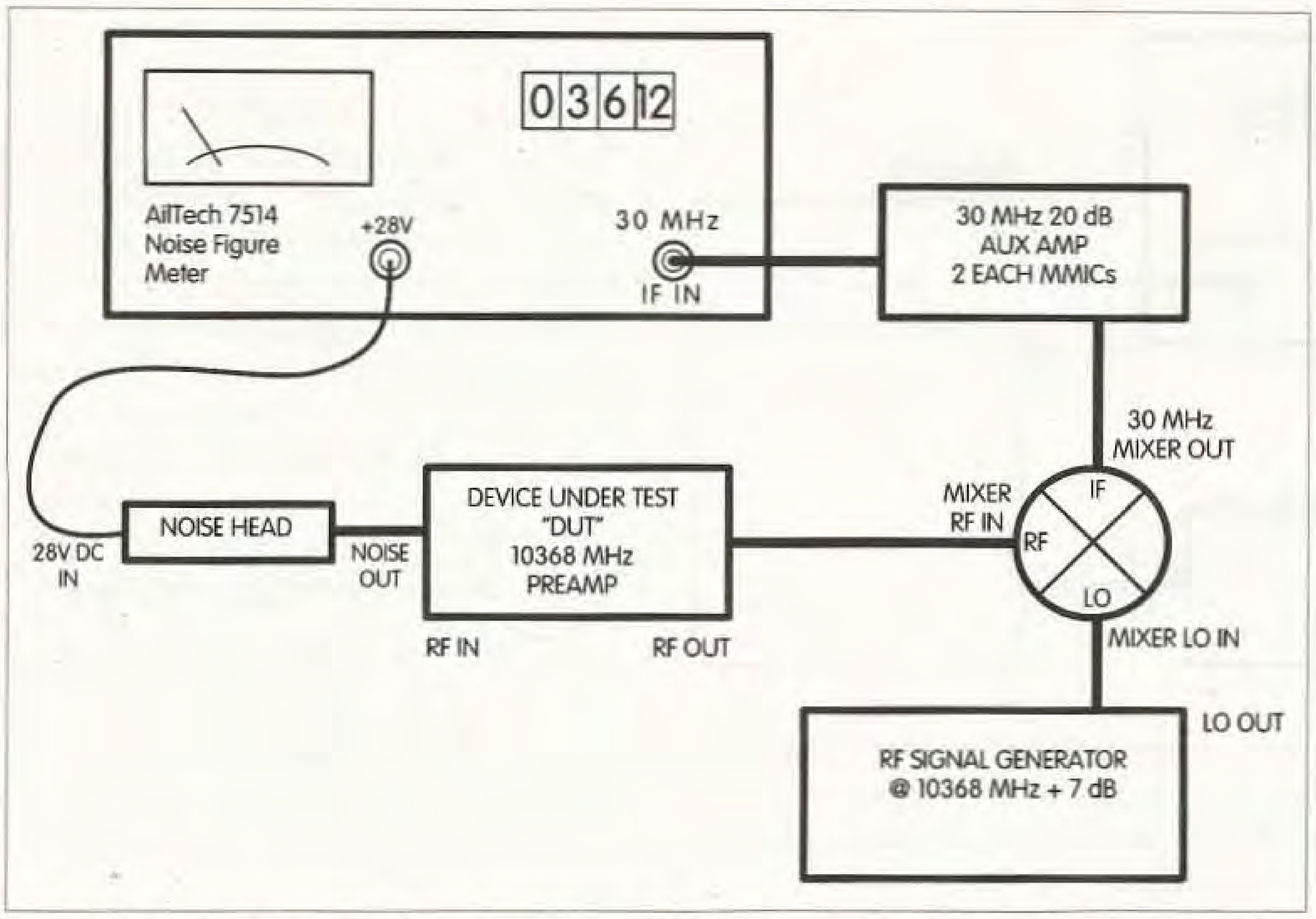

Fig. 1. Ailtech 7514 noise figure meter connected to noise head. Noise head produces RF noise to input of "DUT" (Device Under Test) preamplifier and is converted with an external signal generator and microwave mixer to 30 MHz, the IF frequency of the 7514 noise figure meter. A small 10 to 20 dB amplifier is required to overcome the loss due to mixing conversion loss. 30 MHz preamp can be constructed with 2 stages of most any MMIC amplifier.

1/20 of the tube's weight. Believe it or not, while looking through the junk box that I build from, I located several TIXM0 devices still in their original package. What a find — I had forgotten all about them lying in the junk box from the late '60s. (I should start a radio sideshow of old and interesting devices.)

Since in those days science in general exploded, with 1 dB noise figure at 2 meters came improvements holding the NF to below 1 dB but at increasing frequencies with bipolar devices and then GaAsFET devices. Not to just 1 GHz but into the very microwave region that I love to play in today. Obtaining a 1 dB NF preamp at 10 GHz is nothing today with modern FETs. What is left after constructing such a preamplifier or system is the adjusting and measuring that is required to obtain best adjustment and lowest noise figure (NF). What a comparison to the early 2 meter struggling for a modest noise figure with tubes before transistors and FETs.

Just for fun and to demonstrate how good material is today, I bandsawed a Qualcomm 12 GHz Low Noise Amplifier (LNA) out of a major assembly, put isolation capacitors and two coax connectors on the preamp, and took it to the NF measurement at Microwave Update 1999 in Plano, Texas. It measured at 10368 MHz 27 dB gain, and a 2.13 dB NF out the chute with no prior testing or adjusting by me after sawing the unit out of a much larger component. Compare that to my efforts quite a few years ago with tubes and the first transistors, and you can see that we have come a long way as amateurs, and in electronics in general.

What, then, are the noise improvements that need to be made to a preamp or circuits to make them better and allow weaker signals to be received using the same device and circuit such as my amp described for 10 GHz? The procedures are the same for any frequency, be it 1 GHz or 10 GHz. Only construction and circuit size gets smaller and smaller as frequencies increase, making them more difficult to cope with as circuit size diminishes. Tools shift from longnose pliers and wire cutters to tweezers and Xacto knives. Also, it is necessary to employ a noise figure meter to properly evaluate the circuit for best adjustment for lowest noise figure. The noise figure test equipment must be utilized to make this adjustment. While the preamplifier under test in this example exhibits good gain, minor readjustments in device drain current and bias voltage, with small circuit parameter changes in capacitance and inductance, can turn a functioning preamp into an excellent-low-noise-figure preamplifier.

Well, what does this magical device, the noise figure meter, have that is so special? First, it must have a source of noise, a diode noise source that is calibrated to a specific power in dB (rated in dB or called ENR, excess noise) over a specific frequency range. These specifications are usually labeled on individual noise heads. Its power is called Noise Source Excess Noise. One commercial noise head I have came with a Sanders 5400B noise figure meter (military surplus). This noise head is rated at 25.5 dB (ENR) excess noise from 1 MHz to 18 GHz and flat to within ±.75 dB. That's a lot of noise output power, and if you connected the full unattenuated power of this noise head into a somewhat numb 10 GHz or less frequency receiver, it would jump and take notice. The reaction would be the same as putting 100 microvolts from a signal generator into a receiver that is sensitive to 5 microvolts — that's an S-9+++ signal capable of turning any receiver upside down.

To really find out what is going on, we have to attenuate the noise head power to lesser and lesser levels of noise power and see what the receiver's reaction is, and then calculate the difference between the noise head's noise and no noise at the output of the receiver. The output of the IF amplifier or audio output is coupled to the noise figure meter to make this measurement. What is going on is that the NF meter is pulsing DC power at a 1 hertz on/off rate to the diode noise head. This produces a signal of noise pulses alternating between noise on and noise off. The detector circuit in the noise meter measures the difference between noise on and noise off to produce a reading in dB that is expressed as noise figure. In the noise off state, the ambient noise of the system is measured, and this base line value is compared to the noise on reading. This comparison expresses the true noise figure of the device or converter in dB. The lower the number the better the system amplifier. Adjustments to the amplifier can be made at this time to improve the noise figure readings.

Using a noise head with 25.5 ENR means that noise figure of better than 20 dB can be measured. By modern standards this is quite numb for systems up to 24 GHz. What is done to make lower readings of noise figure possible is to attenuate the noise head power to a lesser value in dB with a 10 or 20 dB attenuator. For a 10 dB attenuator 10 to 20 dB NF can be measured; this might be a starting point for first cut alignment. However, for serious measurements an attenuator of 20 dB is used to make a reading of less than a 10 dB NF. While the Sanders 5400B is an early surplus NF meter, it is not capable of stable sub–2 dB measurements. This is still not to scoff at, as it still

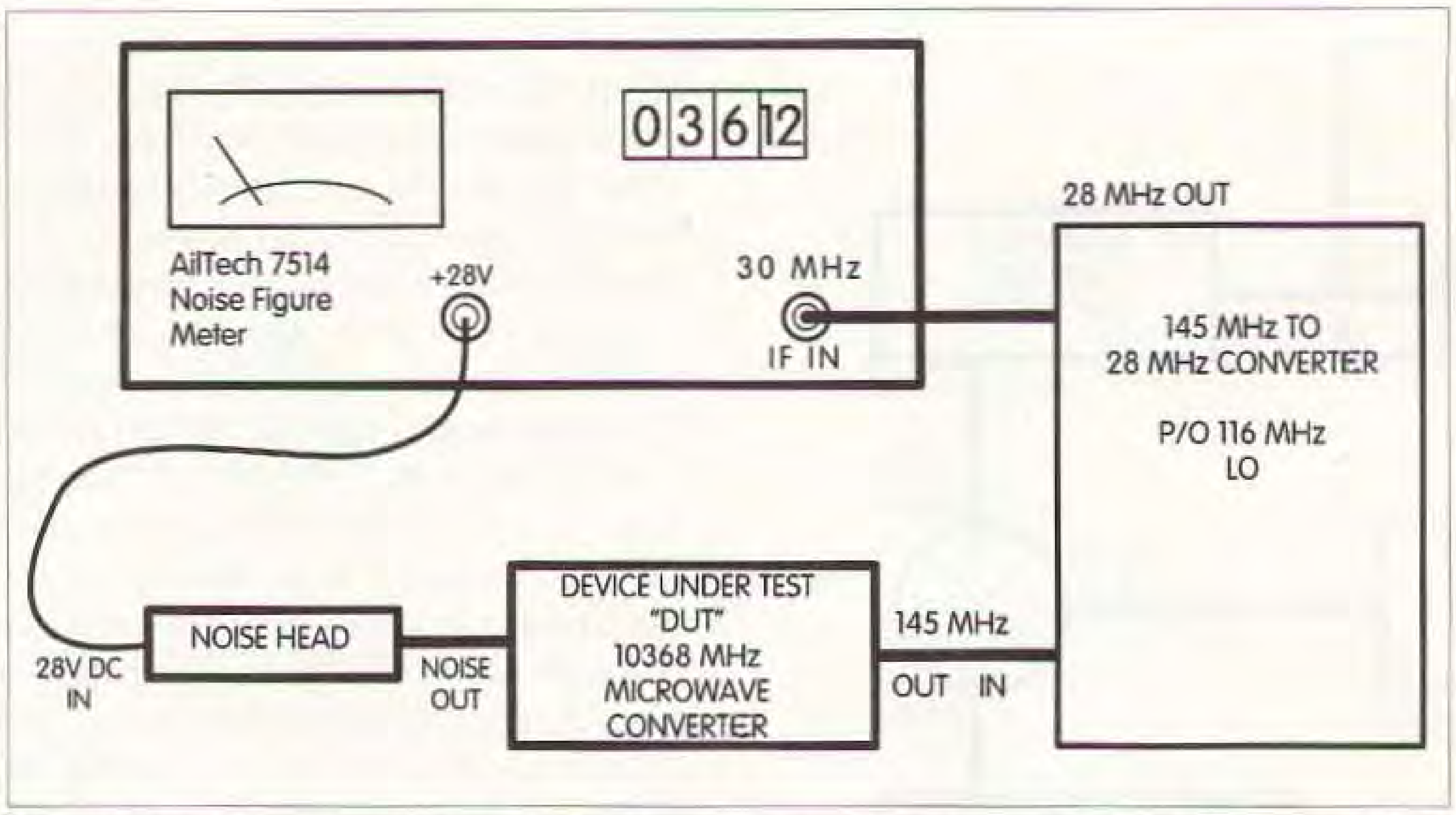

Fig. 2. Noise figure meter testing a microwave converter with 145 MHz IF output. Gain not required at 30 MHz, as converter has high level at 145 MHz IF output. Converter from 145 MHz–28 MHz uses RF mixer and 116 MHz LO crystal oscillator. The noise figure of the microwave converter is now being measured.

can provide meaningful measurements and reasonably good results.

The noise head used in this system is not cheap either, as a good noise head to 18 GHz can run from $400 at used surplus dealers to $1300 new. Keep your eyes open, as they can be had at swap meets for $1 after they are separated from their cables and meters. It seems that most external devices, probes and such, seem to migrate in surplus from the devices that they are used with, making them an orphan item possibly available in unexpected places — especially if you can spot a bargain.

While the Sanders NF meter is quite versatile, it accepts IF frequencies from 10 to 300 MHz — or video input from sources such as the speaker audio jack — to a real wideband video output source. While it is versatile in these applications, it falters in the sub–2 dB noise figure measurements. It's kind of like having a Ford or Chevy while wanting a Ferrari. Well, enter the next level: the Ailtech 7510 through 7514 NF meters. I was able to pick up an Ailtech 7514 meter and NF head that allows RF frequencies to be measured from 1 to 12.4 GHz, and NF measurements to sub–1 dB readings. Just what the doctor ordered.

This meter has one liability, as it has only an IF at 30 MHz as its input frequency. That means that a converter for your IF frequency must be constructed to interface to the NF meter. For all my microwave systems, I use a 2 meter IF for transmit and receive with all converters, so all I need is a 1960s converter for 2 meters to 28 MHz and we are in business. I haven't tried the setup yet, as I'm still gathering parts to put it all into play. Using 28 MHz for an IF should not be a problem, as the 30 MHz IF input is 5 MHz wide. That means that I can use the 2 meter converter in the junk box transistorized and near ready-to-go. I have to add a filter at the IF (30 MHz) and some gain to interface with the IF input circuits, but that can be as simple as a couple of MMIC amplifiers.

There is version -09 for the 7514 NF meter that offers selectable IF frequencies for a great variety, but 2 meters is not one of them. Just a simple mixer local oscillator at 116 MHz and IF preamplifier and filter for 30 MHz is all that is required. Nothing special, as the preamp or microwave converter to the 144 MHz frequency range is the main noise figure determining element in the noise figure measurement. The subsequent stages contribute to the overall NF reading but to a much lesser degree than the first stage device.

I am in the process of building and modifying the converter for the NF meter and will let you know how it goes. Right now I am collecting parts and putting together the full system for bench use. We will finish up this topic next month, with great expectations of having the full noise figure system in operation.

Well, that's it for this month. If there are any questions, drop me a note at my E-mail address. Best 73, Chuck WB6IGP.