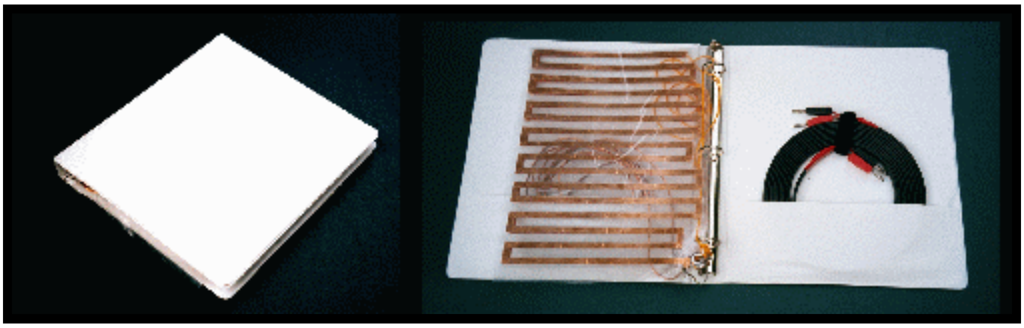
# N5ESE's Notebook Antenna



**A Low -Power Indoor Portable HF Antenna**
by Monty Northrup, N5ESE

NOTE: 'N5FC' is my former call.
This project was constructed while that call was valid, and you may observe references to it.

**Antenna Disclaimer**

Right from the top of this page, I'm going to say that I'm an antenna *experimenter*, not an antenna expert. Purely seat-of-the-pants. In fact, you might even say I'm an antenna cynic. I know how to use antenna analysis tools, and I often do, but I take them with a serious grain of salt. I've found, in my 35 years of experimenting, that some antennas work much better than predicted, and some work much worse (and that they're more likely to work worse than better HI HI ). Still, I find experimenting to be one of those true joys of amateur radio, and I encourage all of you to just "try it out" for yourself, and *for Pete's sake*, **don't** take my word for it (nor my explanations).

I find that most technical people do this (and I am no exception): upon observing a phenomenon, we make up an explanation for why we got our observed results. We base this explanation on the current subset of knowledge that we've gained from education and experimentation and folklore, and we're not likely to look for another explanation until we have another experience which forces us to expand or revise our previous explanation. Please realize this is the case with me, also, and then enjoy the web page.

(Pictures and Diagrams follow the narratives)

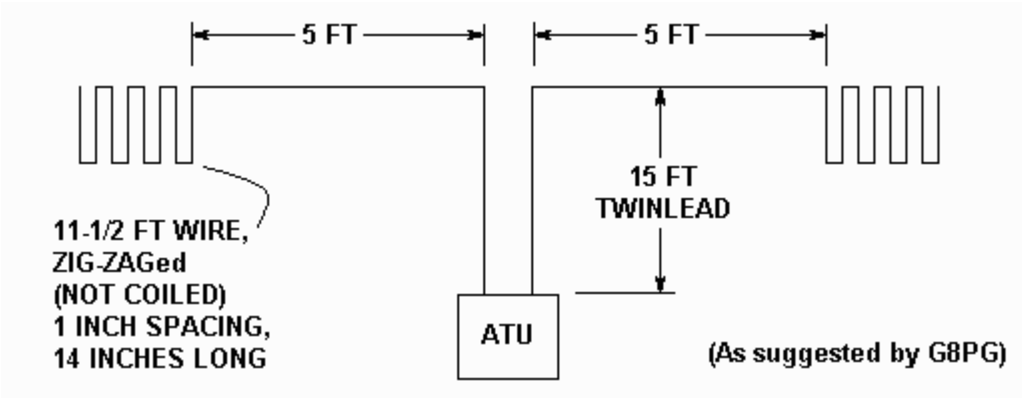
On this page, we'll describe the multiband Notebook Antenna, so called because the entire antenna will fit easily inside a 1" thick 3-ring binder. The antenna is intended for indoor use, with low power (50 Watts or less). It can be easily set up (or re-packed) in minutes. When used with your favorite balanced antenna tuner, it will work on any band from 40 through 10 meters.

## Background

I travel on business way more than I want to. Besides eating at new restaurants, there's not a lot of reward in 12-to-16-hour workdays (which is what always seems to happen to me when I travel). Hamming from the hotel room can be a welcome distraction which helps diminish the sense of isolation one gets while on travel alone. For this reason, I'm always looking for antennas that can be thrown up quickly - indoors, of course - yet still manage to get some RF out into the ether.

To this end, then, I've tried a number of antennas for both receiving and transmitting. Here, I'll present one of the more compact and unusual ones.

In the Fall 1990 edition of SPRAT (Issue 64), Gus Taylor (G8PG) , expanding on material presented by G2MQ, described a 12-foot, 7- band wire doublet. A rough sketch is shown below. In the article, he suggested that one could raise the efficiency of a short antenna by using the entire (1/4-wave) length of wire on each leg, but forming the ends into a "non-inductive" end-loaded assembly. He claimed that such a winding had been found to increase the radiation resistance of a short antenna. And that implies higher antenna efficiency.

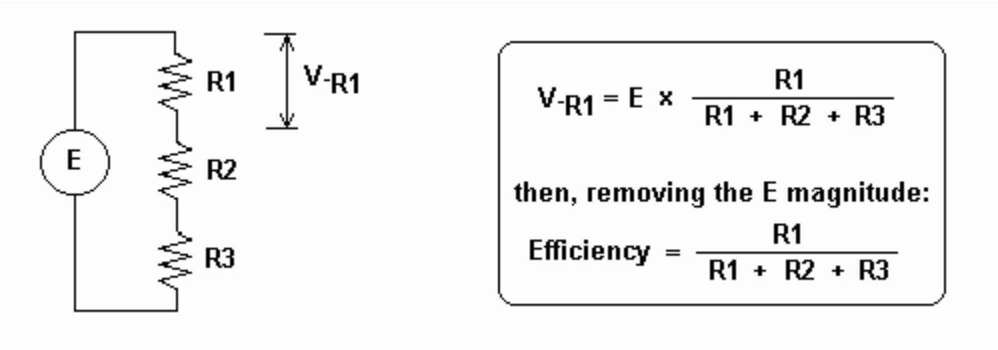



# Antenna Efficiency

Allow me a moment of digression to explain that statement. Radiating efficiency aside for the moment, it should be understood that the sigificantly short antenna (as we are considering here) will probably never receive as well as a full sized antenna, simply because it has reduced "aperture" (meaning it doesn't occupy as much physical space and so cannot extract as much energy from the available space). We'll overlook the shortcomings of small antennas as receiving devices, since modern-day receivers usually have sufficient reserve gain to accommodate the needs of most portable operations. Having said this, however, we *can* use efficiency as a measure of the ability of the antenna to inject energy into the available space, and make the relative task of increasing efficiency a worthy goal for improving antenna performance.

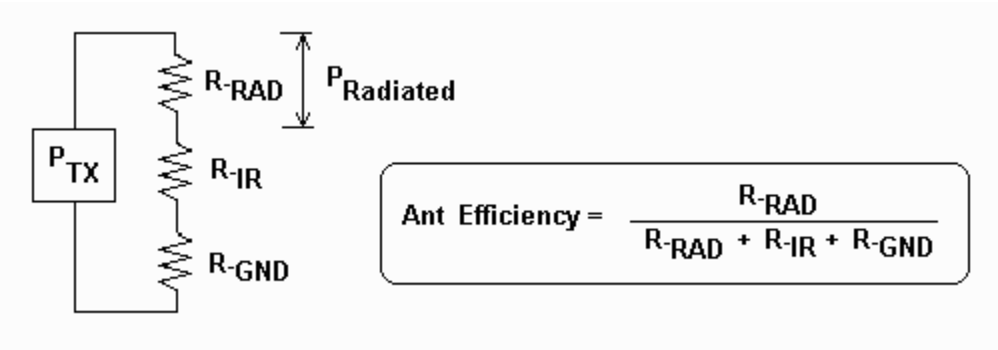
The first problem one has with short antennas is getting the power from the transmitter to the antenna. An antenna tuner is the most common (and probably most expeditious) way to accomplish that. In a balanced antenna such as this, getting a good match is not too hard. Let's say, for example that you operate QRP (like me). The transmitter generates 5 Watts into a 50 ohm load. You adjust your transmatch (antenna tuner, or ATU) to get a 1-to-1 SWR at the transmitter. If you consider the feedline to be part of the antenna (it usually is, in a portable), then once you have your match, you have most of the power getting to the antenna. That power has to go somewhere. In a full-sized antenna, without obstructions, over a good ground, you'll get 95-99% of that power radiated. That's good efficiency.

Antenna efficiency has been described in terms of radiation and loss resistances, and I find it useful to think in these terms. It's kind of like voltage in a bank of series resistors. Remember the formula? If we have three resistors R1, R2, and R3 in series, and connected to a voltage source E, the voltage across the first resistor is expressed as shown below. If you throw away the voltage *magnitude* what remains is the **percentage** of source voltage E that will appear across R1.




> NOTE: Please don't write to me complaining that the formula fails to address loss 'X' or condition 'Y', or that it isn't a mathematically correct model of antenna behavior... that is not our purpose here. Rather, we intend this model to serve as an analogue for conceptualizing how these parameters affect radiating efficiency. And to that end, this model works well (my apologies to the academics)

Well, thinking about antennas again, if we use this model, R-RAD (formerly R1) represents the Radiation Resistance, i.e., the part that's actually going to do the work and radiate into space. R-IR (formerly, R2) represents the IR losses, i.e., the wire or copper losses (this really IS resistance). And R-GND (formerly R3) represents ground losses. Now let's see our formula:




Notice a few things about the formula:

- As we've shown them here, the result is fractional (multiply by 100 to get percentage)
- There is no combination of resistances that will give you more than 100% efficiency
- The higher R-RAD (radiation resistance), the higher the efficiency
- The higher the R-IR or R-GND, the lower the efficiency

For example, a resonant half-wave dipole will typically exibit an R-RAD (radiation resistance) circa 70 ohms. Typical R-GND (ground losses) might vary from 5 to 100 ohms (sorry!), depending on soil type and moisture level. Wire resistance R-IR (copper losses) might be an ohm or two or three, depending on your wire size, solder joints, and connector quality. So, given this, we can expect an efficiency of 40 to 92%. For our 5-watt transmitter, that means between 2 and 5 watts radiated, approximately. Quite usable.

But short wire antennas present a serious problem for radiation efficiency. A doublet's radiation resistance decreases as it shortens. For example, a 40 Meter doublet with 33 foot long legs would show a radiation resistance of around 70 ohms; shorten that to 5 or 6 feet, and the radiation resistance becomes 2 or 5 ohms, or less... suddenly. for the same ground and wire losses, we're talking about radiation efficiencies of between 2 and 25%. Yikes! Now, for our 5-watt transmitter, we're only radiating between 100 milliwatts and 1 watt.

As anyone knows who has tried to use a short or otherwise down-sized antenna, all this translates into poor performance. As we can see (by plugging in the numbers), if we have to deal with a short antenna, we have three choices for improving antenna efficiency:

- raise the radiation resistance;
- lower the ground resistance;
- lower the IR losses (copper resistance and connection resistance).

In some portable situations, either by convenience or necessity, getting a good ground is a matter of pure chance, or worse yet, no chance at all. For example, when operating in a hotel room, there often are no available grounds except the electrical service ground (placing RF on an unknown electrical ground system is a bad idea). A 1/4 wave counterpoise can help, even if you have to lay it down in gentle S-curves because of space restrictions. Using a balanced antenna also helps, and usually eliminates the need for a counterpoise.

Lowering the copper losses in a portable situation can also be inconvenient. Yes, you could use 12 guage wire, but it's weighty and cumbersome to handle. And if the antenna has to be portable, connectors may rely on mechanical joints instead of solder joints, leading to more losses and lower efficiency. Still, this is an area that can be easily controlled, and often improved.

That leaves us with radiation resistance... huh? you say... There are a few things that folks (smarter than me) have discovered that can raise radiation resistance in shortened antennas. Capacity hats are one, usually at the end of the radiator. The technique described here is another. While I can't vouch for the *reasons* suggested by the author as to why this improves efficiency, he claims (quoting):

> *"The method was simple: to whatever length of wire could be erected, was added a further quarter wavelength of wire, wound in a series of narrow U-shapes... Adding this non-inductive loading... the radiation resistance of the wire was increased, sometimes dramatically. For example, at 1.8 MHz the radiation resistance of a 15 foot wire should be increased by a factor of 14, and that of a 66 foot wire by a factor of 4."*

## A Practical Antenna

Using these thoughts as the foundation for an antenna design, I endeavored to come up with something both practical and usable for operating QRP from a hotel room. Whips have been used but are notoriously inefficient, and certainly won't fit in my suitcase. Wire loops have also been tried, and are either hard to tune or very inefficient when less than a full wave long (there are exceptions, like the DCTL antenna, which I describe here). Magnetic loops are very, very efficient, but are hard to fabricate, expensive commercially, and cumbersome to transport. I wanted an antenna that was *very* portable (i.e., fit in my briefcase), easy to set-up and take-down, and reasonably efficient (or at least, relatively so, compared to other equally portable antennas). The Notebook Antenna is the result of my efforts.

Some time ago, I found that hobby stores (like Hobby Lobby and Michaels) carry adhesive-backed copper-tape. The 1/4 inch-wide tape is approximately equivalent to AWG 25 wire (in cross-section), and two in parallel equal about AWG 22. This would be quite usuable (and believe it or not, quite solderable). Now, instead of using wire and boxes to "wind" the non-inductive end-loaded parts of the antenna, I'll use an 8-1/2 x 11 inch (letter-sized) transparency, and lay the tape down, zig-zagging on both sides (in parallel). I'll make two, of course (one for each leg of the doublet), and I'll punch holes for a three-ring binder. The transparency might easily tear if excess force is applied, so we'll place an eyelet on the top-inside corner (the kind found in cloth stores), and thread our support rope and antenna wire into this eyelet. The support rope (a small diameter nylon string) will pass through the transparency's 3-ring binder holes, to keep it in place, but the eyelet will take all the strain. For the antenna wire, we'll use AWG 16 wire (although AWG 18 would work as well), and we'll feed the antenna with 15 feet of low-loss twinlead, as suggested by the author. The pictures below will tell the story far better than I can in words. I suggest you use a 1/4-wave counterpoise (at your antenna tuner ground) when using the antenna on 30 or 40 meters; none should be required on 20 through 10 meters.

# Construction

Materials:

- 2 ea Transparency Sheet, 8-1/2 x 11 inches (available in office-supply stores; I used Apollo p/n WO100C-25, 25-pk approx $11)
- 4 ea Adhesived Laminating Sheet, 9 x 12 inches (available in office-supply stores; I used Avery p/n LS10P 73603, 10-pk approx $8)
- 2 ea Eyelets, 1/4 inch I.D. (available from cloth/sewing supplies; I used Dritz p/n 659-65 "Large Eyelet Kit, which included a tool", kit approx $3)
- 12 yds Copper Foil Tape, adhesive backed, 1/4" wide, 1.25 mils thick (available from hobby/craft stores; pn/mfg unknown; 36 yd roll approx $6)
- 11 feet AWG 18 or 16 stranded wire (insulated or not, your choice)
- 1 foot AWG 24 or 22 stranded wire (insulated or not, your choice)
- 1 ea center insulator (dual-binding post RS 274-718 approx $4, or scrap plastic, or ??? small and light)
- 15 feet 300-ohm twinlead (I used Radio Shack15-004, 40-ft-pk approx $3)
- 10 feet 1/16 inch braided nylon or polyester cord
- 2 ea coffee-cup hooks (screw-in type, small)
- 1 copy template for foil zig-zag
    - JPEG File... print at 180 dots-per-inch, margins set to zero
    - Word97 File... use MS Word97 or WordView97 (available free)

# Assembly

1. Using the template provided (or working with your own pattern):

- Place one sheet of transparency (long side horizontal) in front of you on the table, and on top of the template.
- Locate the eyelet hole about 1/2" inward of the upper right-hand corner.
- Begin to lay copper tape onto the transparency, using the template as a guide, and beginning at the upper right (near the eyelet hole), then bringing the tape toward you. Leave about 1" extra at the start, and folded so as to extend of the right side of the sheet, to form a pigtail for use later.
- When you reache the bottom of the page, make two folds in the foil tape (without breaking it) so that the tape effectively makes a 90-degree turn.
- Lay the copper tape 1/2-3/4 inch, then make another 90-degree turn, so that the next lay of tape will parallel with the first.
- Continue with this zig-zag pattern until you fill the transparency with 11-1/2 feet of tape (138 inches), avoiding the locations of the eyelet and three (3-ring) binder holes, which will be used later.
- When you finish the first side, turn the transparency over, and lay a second piece of tape exactly in parallel with the first (but on the opposite side of the transparency) Again, use a pigtail on the eyelet side, which may now be "stuck together" with its counterpart.
- When finished laying tape, smooth it down firmly to maximize adhesion.
- Attach a 2-inch piece of AWG 22/24 stranded wire to the pigtails near the eyelet location. Solder the wire to the foil, close to the transparency, but not so close as to melt it.
- Cover the foil and transparency on both sides with the self-adhesive laminate sheets, sealing it, but leaving the 2" wire pigtail free.
- Install the eyelet 1/2" inboard from the corner near the pigtail.
- Punch the completed end-loading assembly for a 3-ring binder.
- Repeat the entire process to construct the end-loading assembly for the second doublet leg.

2. Assemble the doublet:

- Cut two AWG 18 stranded wires to 5 feet, 6 inches long. If insulated, strip 4 inches on each end.
- Attach the 15 foot twinlead and the two 5 foot wires to form a doublet with feeder, using your chosen (small, lightweight) center insulator (if you like, these can be mechanical connections - I used a dual binding post - but remember that high-ohmic connections in a short antenna can seriously degrade antenna efficiency).
- Strip the far end of the twinlead as appropriate for connection to your antenna tuner

3. Attach the doublet to the end-loading zig-zag sheets as follows:

- Use the excess wire (excess of 5 feet, that is) of one doublet leg, threading it through the eyelet (of the end-loading assembly), and wrapping it back on itself. Leave the eyelet loop very loose.
- Connect the free end of the end-loading assembly's wire-pigtail to the doublet leg, wrapping securely. Solder the connection. When complete, the doublet leg should be free to move in the eyelet, and the pigtail should move with enough slack that it will not pull on the copper foil.
- Loop the 5-foot nylon cord through the loop in the doublet leg (in the eyelet) and knot it securely there. When done, the nylon cord will support the doublet leg and the eyelet will support the end-loading assembly, and neither will

stress the end-loading assembly.
- Thread the nylon cord (already attached to the doublet leg) through the remaining (3-ring-binder) holes, leaving about 4 feet free.
- Repeat the process for the other doublet leg.

# Operation

Installation and tune-up takes place as follows:

- Near on on the ceiling, screw-in-place two cup hooks about 12 feet apart. Think about and avoid proximity to AC power/noise sources and appliances.
- Using the free ends of the nylon cords, hang the antenna on the cup hooks.
- Attach the twinlead feeder to your antenna tuner (and your center insulator, if using mechanical connections). For maximum effectiveness, your antenna tuner should be a balanced-output design.
- CAUTION! Consider the bio-effects of using this antenna just as you would any other antenna. For more information, look -here-
- Tune for minimum SWR on the transmitter-to-antenna-tuner transmission line. NOTE: For 20 - 10 meters, no counterpoise should be needed. For 30 and 40 meters, improved efficiency may be obtained by using a 1/4-wave counterpoise, attached to the ground/chassis of the antenna tuner or transmitter. If you don't have enough room to lay the counterpoise straight, lay it on the floor in gentle S-curves. If your tuner has difficulty tuning on 30 or 40 meters using the balanced feedline, tie the feedline togther and feed it like an end-fed wire (in this case, you'll definitely need the counterpoise)

# Results, and My Impressions

My first QSO from central Texas, with the antenna hanging from coffee hooks placed in the ceiling of my first floor bedroom, and using 5 watts on 15 meters, was with Brian VE3ADX, in Ontario, who gave me a 549. We QSO'd for 8 minutes with no problems. My second QSO was on 20 meters, again 5 watts, with Rusty KC4ZPB, in Tennessee, who was also QRP, and who gave me a 559. We QSO'd for nearly half an hour. The antenna is a little more susceptable to power-line radiated noise (than is an outside dipole), and this can be problematic in some locations. While received signals were down about 1-1/2 to 2 S-units (as compared to the full-sized outdoor dipole), the power line hash was not similarly reduced. Of course, it *was* indoors (and hence closer to power lines). Efficiency? Who knows... but IT WORKS! ...73, Monty N5ESE

Update: Sverre, LA3ZA, is kind enough to share his very encouraging comments and experiences on the Notebook Antenna (click -here-)

### Pictures and Diagrams:

Antenna stored in 3-ring binder, for transportation [34Kb]
End-loading Foil Assembly/Sheet and connections [for high-res screens, 72Kb]
End-loading Foil Assembly/Sheet and connections [for 640 x 480 screens, 38Kb]
Detail, end-load assembly joint [for high-res screens, 105Kb]
Detail, end-load assembly joint [for 640 x 480 screens, 62Kb]
Template, foil-winding [JPEG, print at 180 dots-per-inch, margins set to zero, 115Kb]

Template, MS Word97 File, for printing [29Kb]... use MS Word97 or WordView97

---

Return to N5ESE home page

---

Overseer: Monty Northrup ... ... leave e-mail ...

Visit our regular (non-ham, but very popular) homepage