Balloon-Supported Antennas for HF

How to really get out on 80 and 160 meters

by Stan Gibilisco W1GV

The idea of using a helium-filled balloon as a support for an antenna is certainly not new, but it is rarely done. Contrary to many ham's opinions, however, flying a "balloon vertical" or "balloon sloper" need not threaten either the pocketbook or human lives.

Initial Considerations

Certain things were obvious right from the beginning when I made my plans to fly a ⅝-wave end-fed antenna for 160 meters. The materials must be readily obtainable. The wire must be lightweight, conductive, and strong. There should be some provision for keeping the balloon from taking the antenna away. This last item is quite important because a long conductor, trailing from a large, lighter-than-air balloon, can be a hazard. It will eventually come down—perhaps draping the antenna over a power line.

The balloon itself has to be large enough to lift the antenna and to keep it up in a moderate breeze. I found 40-inch (about 1-meter) balloons for a few dollars that worked well for winds up to about 20 miles per hour and antenna lengths up to about 500 feet which used A.W.G. #20 (0.030-inch or 0.762-millimeter) aluminum welding wire. At higher wind speeds, stability was poor and several balloons plunged into tree branches and popped. Future plans include kite/balloon combinations to allow greater flight stability in higher winds, wind shear, gusting, and down drafts.

The most important consideration is: don't attempt balloon flight when there's any chance that the wire will hit a power line. Fortunately, I live in a neighborhood where most of the utility lines are underground. The nearest above-ground power lines are over 950 feet (290 meters) away. Allow a few percent for error in estimating the distance to a power line. I set the upper limit of my system to 900 feet (about 275 meters)—still more than a full wavelength at 1.8 MHz.

The antenna doesn't have to be any particular length, although it's best to choose a length near an integral multiple of ½ wavelength. At these lengths, the resistive component of the impedance is high, minimizing ground losses. In Figure 1, the variation of complex antenna impedance, end-fed over perfectly conducting ground, is shown for vertical antennas for increasing height. At heights less than ¼ wavelength, (the graph curve up to point A), the resistive component is extremely low. As the height increases beyond ¼ wavelength, where the resistance is about 37 Ωs, the resistance continues to increase. It reaches a maximum at ½ wavelength (at point B) of perhaps 600 to 800 Ωs. With a thin wire, the value will be very high, resulting in low ground losses with even a marginal grounding system. Matching techniques for ½-wave radiators are well known. Figure 2 shows two popular matching devices—the quarter-wave section of open-wire line and the tuned tank circuit.

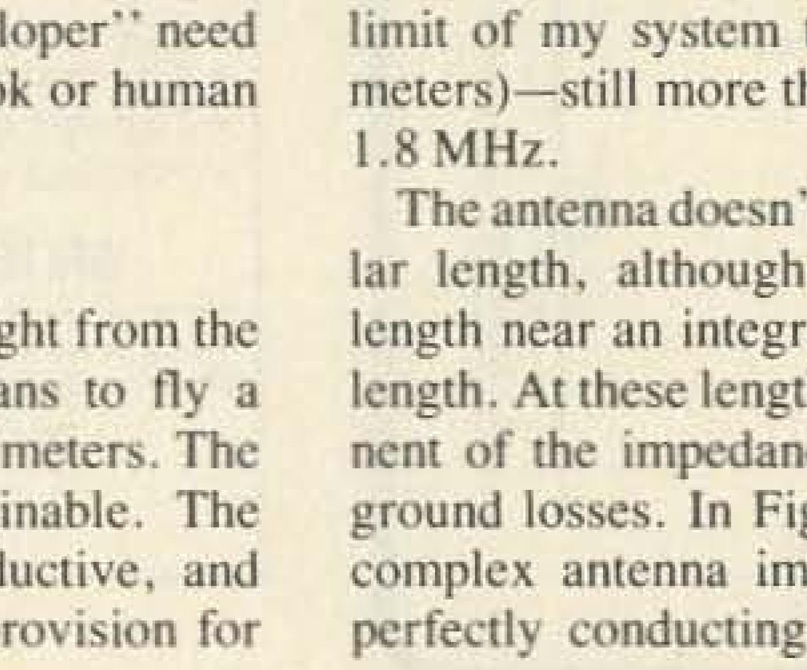

Figure 1. Reactance/Resistance relationship for an antenna from 0 to 1¼ wavelength high (point E).

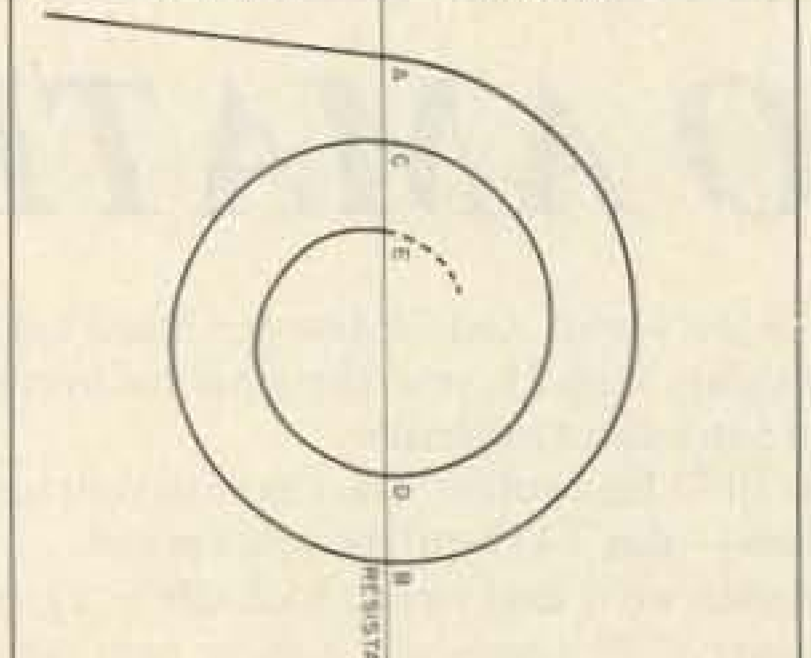

Figure 2. Two common matching systems for the balloon antenna.

Refer again to Figure 1. As the antenna length increases beyond ½ wavelength, the resistance decreases again, and reaches a minimum at ¾ wavelength (point C). This value is somewhat higher than the value at ¼ wavelength because of the extra resistance that occurs from radiation. Further increasing the height makes the resistance rise again, where it reaches another maximum at 1 wavelength (point D). Because of radiation, this value is less than the value at ½ wavelength. Continuing the increase in height produces a characteristic converging spiral in the complex R + jX plane, centered around a point on the R axis at about 180 + jO. It can be seen that the reactance alternates between capacitive and inductive, being zero whenever the antenna has a height that is an integral multiple of ¼ wavelength.

If a balloon-supported antenna is perfectly vertical, ideal heights for omnidirectional low-angle radiation are in the range of ½ to ⅝ wavelength. At 1.810 MHz, ½ wavelength is represented by 259 feet (78.8 meters) and ⅝ wavelength by 323 feet (98.5 meters). These lengths are determined by the formulas:

$L_{0.5\lambda}$ (feet) = 468/f MHz

$L_{0.5\lambda}$ (meters) = 143/f MHz

$L_{0.625\lambda}$ (feet) = 585/f MHz

$L_{0.625\lambda}$ (meters) = 178/f MHz

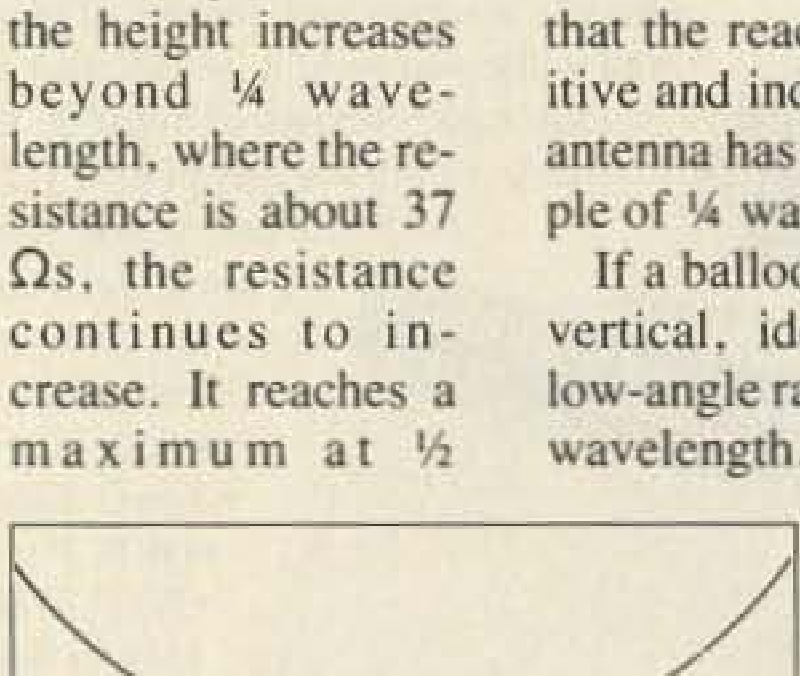

Figure 3. Stoppering the balloon after inflation. The cardboard disk acts to stabilize the balloon in winds.

Antennas supported by balloons, however, are rarely straight up and down. Even a slight wind produces considerable slanting of the antenna. If the wind is sustained over 20 miles per hour, it becomes difficult to keep a balloon antenna from breaking apart or coming down in a gust. My experience is that long wires supported by small balloons almost always are "slopers," not verticals. Therefore, for low-angle directional propagation, lengths greater than ⅝ wavelength become quite practical and useful. To date I have flown lengths up to 830 feet (253 meters), representing about 1.6 wavelengths at 1.810 MHz.

The Basic Design

The components for the basic balloon antenna cost under $100. I left out the costs of the antenna tuner—a fundamental component for a system like this—and the ground radial system, which you should consider installing. Several radials of ¼ wavelength or greater, laid on or just under the ground, minimizes ground losses and optimizes antenna performance. Such a system also reduces RF in the shack.

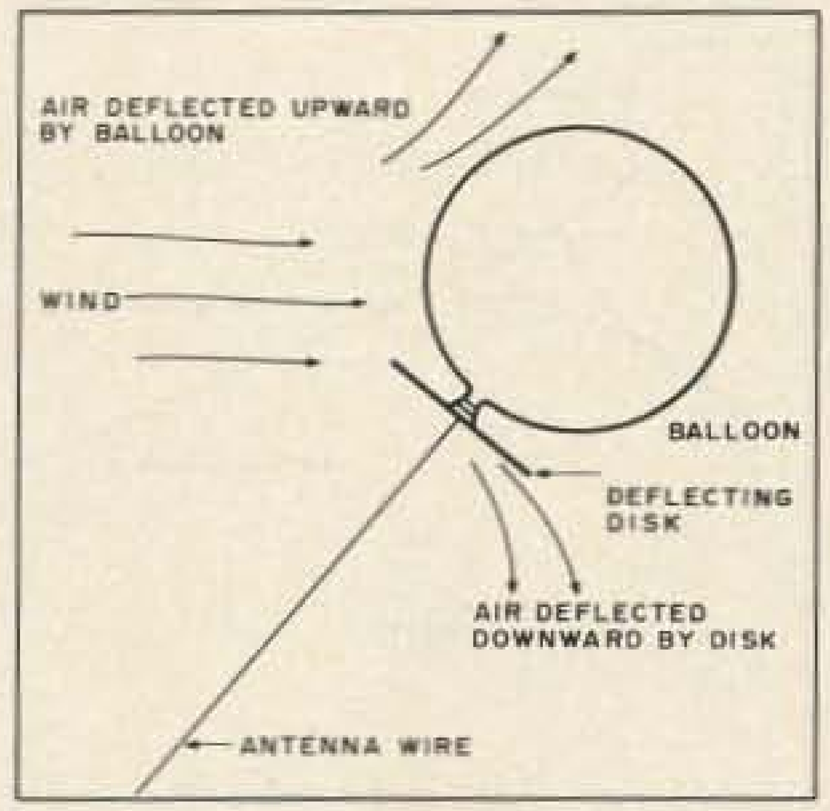

Figure 4. How the cardboard disk stabilizer serves to stabilize the balloon in winds. The upward force from the disk balances the downward vector caused by air flowing around the balloon itself.

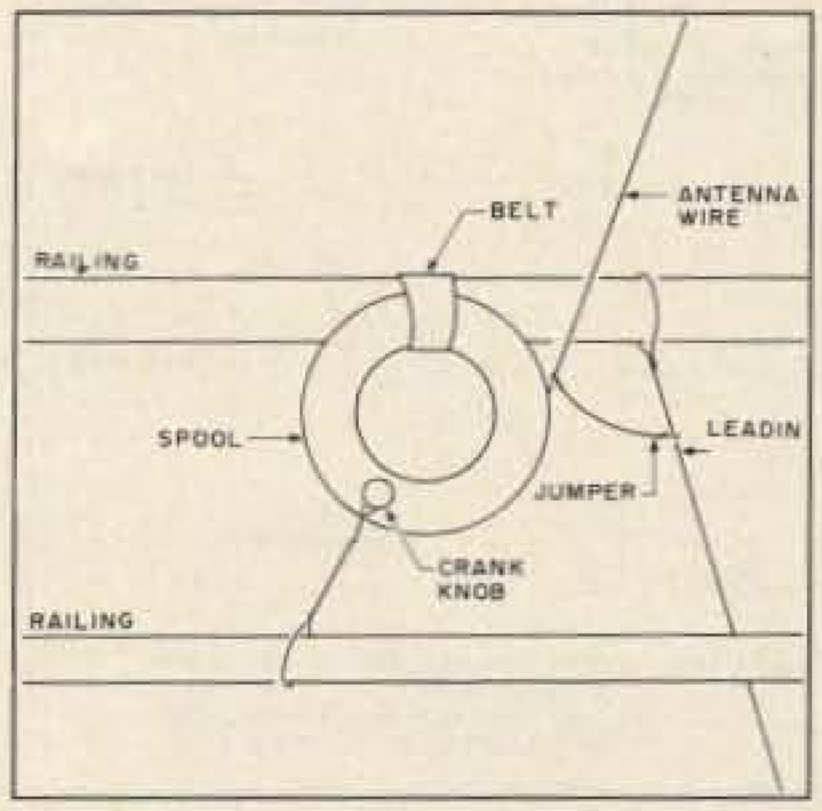

Figure 5. Base mounting scheme for the balloon antenna.

The original motivation for this experiment was the 1988 CQ Worldwide 160-meter CW DX contest. I planned to fly a ⅝-wave antenna for 1.810 MHz. The wire was A.W.G. #20 (actually specified at 0.030 inch diameter) hard aluminum welding wire, uninsulated, single-strand. The height was trimmed by adjusting for minimum SWR at 3.620 MHz, the second-harmonic where the antenna would be 5/4-wave resonant and present a fairly good match to 50 Ωs (it turned out to be 1.2:1). A 110-yard (about 100-meter) roll of 20-pound monofilament fishing line was run out along with the wire to act as a backup if the wire broke. This gave a good indication of the initial length of the wire, and ensured that the antenna really was being tuned for 5/4 wavelength at 3.620 MHz and not ¾ or 7/4 wavelength.

It was necessary to trim about 20 feet (6 meters) off the line for resonance, and this seemed about right since the lead-in to the shack was 15 feet (5 meters) from the base of the antenna.

The balloon, a 40-inch display balloon, proved to be unstable in even a slight wind, so a stabilizer was added by tracing a cardboard disk around a 33⅓-rpm phonograph record and placing it at the base of the balloon as shown in Figure 3. This device acts to deflect air downward when the balloon slopes in a wind. The balloon is thereby stabilized at the angle where the upward force from the disk balances the downward vector caused by air flowing around the balloon itself (Figure 4). This results in substantial improvement in stability, with much less bobbing and dipping, and a diminished threat of the antenna coming down because of a catastrophe with a tree branch.

Even with the stabilizer, I don't recommend flying the balloon in a wind of more than 20 miles per hour sustained, as the balloon may come off the end of the wire. Two balloons were lost this way, one prior to the contest and another after one hour, nine minutes of operation at the 77th contact. At this point, the stable antenna, an 880-foot (270-meter) longwire, was used. It's always a good idea to have such a backup antenna when a balloon antenna is used, so there is something to fall back on if conditions become too adverse for balloon flight.

I wound the wire, along with the fishing line, onto a spool intended for utility cords. The spool provided about 18 inches (perhaps 50 cm) of length per turn and made it easy to retrieve the wire without tangling. The spool was anchored to the railing of the sundeck with a pants' belt. A wire wrapped around the railing and tied to the crank knob of the spool provided additional anchoring. The wire to the shack was clipped to the antenna wire with an alligator clip. The whole base-mounting scheme is shown in Figure 5.

Of course, you don't need to watch the balloon to know a catastrophe occurred with the system. When the wire came down shortly after the contest began, the linear let me know right away by emitting a profoundly disgusted hiss. Signals dropped off to almost nothing. The SWR on the antenna tuner skyrocketed and all operations were momentarily suspended. Conditions improved the second night of the contest.

Inflation Process

The balloons I used had necks that fit directly over the helium tank valve, without the need for a special nozzle. Rubber bands secured the balloon to the valve. Inflation was done in the garage with the door down to keep air currents to a minimum, with the cars outside and the ceiling lights off.

Take care to keep the balloon away from sharp objects like hanging shovels, rakes and brooms. I inflated the balloon slowly to keep it from blowing off the tank, and so I would not accidentally overinflate and pop it. When the balloon was properly inflated, I pinched the neck and put the stopper in it, securing the neck tightly around the stopper with rubber bands. The balloon was then tethered to a short string, using the screw hook in the stopper, and the other end of the string was tied to a 5-pound dumbbell. It is surprising how much weight a balloon this size can lift. It took a medium-sized hammer up! Be sure to use sufficient securing weight.

Bringing the balloon outside requires a tight grip on the base of the balloon as well as on the dumbbell or whatever weight is used. Slight gusts of wind will send the balloon into wild gyrations and it could easily hit a twig or the corner of the eaves and pop. As soon as the antenna wire is connected to the base of the balloon, the balloon should be let up so that it will be out of the way of the roof or low trees. Stability improves when the balloon is clear of objects that create wind turbulence. It should not be left at great heights unattended or for long periods during the daylight hours, as a mishap can occur and neighbors might get inquisitive (along with half the country if the balloon is high enough).

Determining The Best Height

This kind of antenna is especially useful on 80 or 160 meters. Normally the ⅝-wave height is best for all-around use. The length can be measured by determining the circumference of the spool, with the wire fully wound on it, and then counting the turns by feeling the knob thumping on your hand. It is important to add the length of the lead-in when determining antenna length. Don't expect exact resonance—a ⅝-wave radiator is nonresonant anyway. The reactance is tuned out by the transmatch at the station.

It's sometimes desirable to use heights greater than ⅝ wavelength. When this is done, precautions must be taken to ensure that the antenna cannot fall on a power line. There is increased risk of such problems as the wire coming down on television antennas, neighbors' cars, houses, and such things. The slope and tension will increase as the balloon is flown higher. The aluminum welding wire that I used, about A.W.G. #20, gives approximately 1200 feet (366 meters) per pound. This can be lifted by the balloon I chose, and is about as long as any wire that any ham is likely to want to use. The length of the wire will determine the cones of maximum radiation around the antenna. As the wire is made longer, the cones become sharper—that is, the angle of the apex decreases. Minor lobes also appear. A complete discussion of this subject would require a long article or book chapter all by itself, and there is simply not space here for it. Longwire antennas are discussed in *The ARRL Antenna Book*, where detailed illustrations of the maxima are given.

Considering that the maximum length of a balloon antenna is two wavelengths at 160 meters, there will not be appreciable gain resulting from the major lobes of a longwire of this size. There will be excellent low-angle radiation in some directions, however, and it may be expected that these maxima will provide superior low-angle radiation compared with any other kind of 160-meter antenna available to most amateurs. For example, a 1.5-wavelength wire at 1.810 MHz will measure 777 feet (236 meters) and will have maxima in a double cone with apex angle about 43 degrees, and also in the plane perpendicular to the wire. If this wire flies at an angle of 43 degrees up from the horizon with a wind from the north, there will be low-angle maxima toward the North and South, and also toward the East and West (Figure 6). These result from phasing at quite high locations above the ground and will be essentially the same as if the antenna were in free space. There will be radiation at somewhat elevated angles in various directions. The actual pattern is rather complicated, but with a bit of imagination you can envision the radiation pattern in three dimensions.

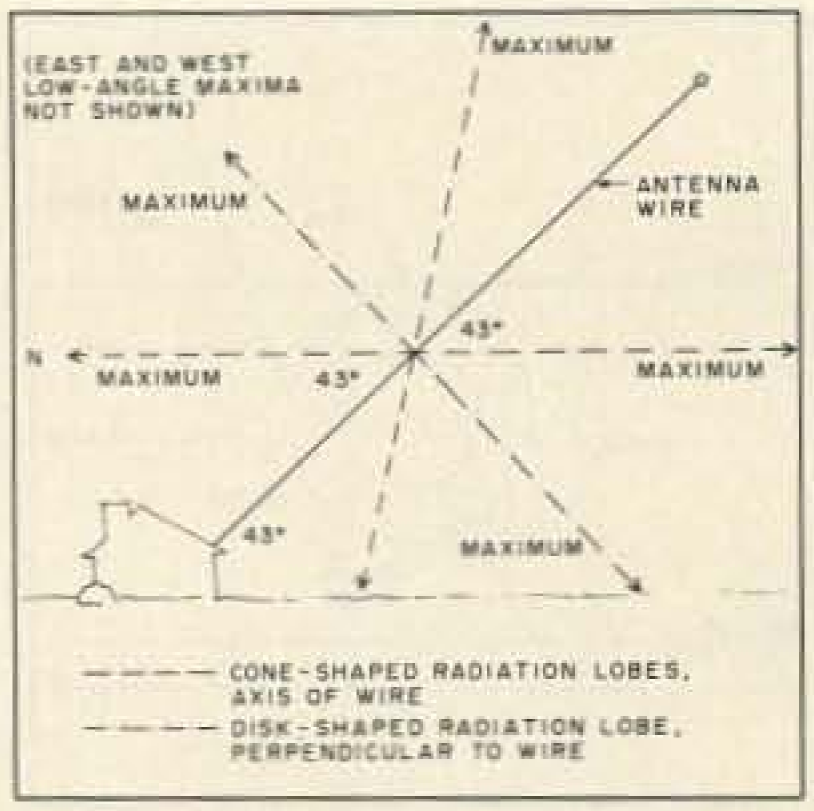

Figure 6. Radiation patterns for a 1.5 wavelength wire at 43° to the horizon. This is an excellent low-angle radiator.

We have no control over the wind direction, but we can change the length of the wire and obtain maxima at low angles in any desired direction, no matter what the wind direction. Winds do change frequently, though, and if you get very serious about balloon antenna operation you may find yourself listening to NOAA Weather Radio quite a lot. It's helpful to know when to reel in the balloon!

Again, don't forget to tether the balloon with fishing line along with the wire, so that the balloon will not be likely to take the wire with it if there is an accident.

The Impermanence of It

I have wondered why this kind of antenna is not used more often by enthusiasts of 1.8 and 3.5 MHz, and I think I have some idea. First, and quite legitimately, many hams are in areas where this kind of project is impractical and perhaps even dangerous. A trip to the country, QRP style, is an alternative in these cases. You may want to try this for Field Day on 80 meters and possibly even 40 meters. It's worth a try from a temporary location. Don't do anything that might endanger your life or someone else's life by trying this near power lines, however.

Second, this kind of antenna seems impermanent, flimsy, and even "hokey" to some because it may be brought down by mischievous winds or birds, and because it is subject to so many variables. It may even seem like cheating to use a balloon support. But it *works*. The loss rate is considerable no matter what you do, but it's still fun while it lasts.

On The Air

The first thing I noticed when I flew my first balloon—a ⅝-wave 160-meter slanting vertical—was noise. It is evidently no misconception that a wideband vertical will pick up tremendous amounts of noise, often S-9. Signals were often as high as S-9 + 30, while on my 880-foot (270-meter) longwire the signals were rarely of that caliber. Even so, it was often true that signals were readable on the longwire, with noise levels of S-2 or S-3, which weren't readable on the vertical. I therefore set up an arrangement with a separate receiver so that I could listen on the longwire while transmitting on the balloon-supported antenna.

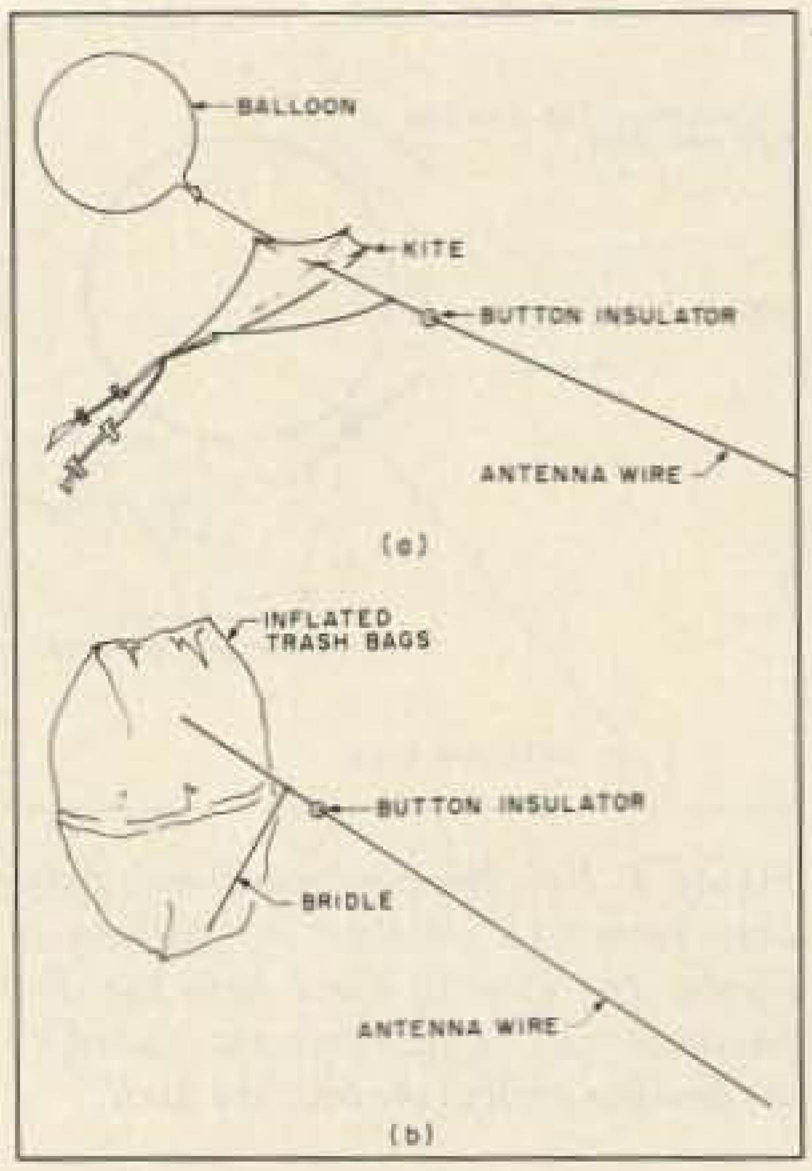

Figure 7. Several balloon antenna arrangements.

Results were immediately gratifying. I tuned up to 500 watts CW output, the most power I dared to use on that thin wire. Signal reports were quite routinely S-9-plus. It wasn't unusual to hear any report less than 589. I did not work any DX, except for the Virgin Islands, Puerto Rico and Alaska, but this is probably because I didn't have the appropriate system of beverage antennas that is best for hearing DX at 1.8 MHz. On 80 meters I easily worked JA stations, hearing somewhat better on that band with the balloon vertical since the noise level was a little more reasonable.

In the contest, stations that are well known for holding frequencies, were calling *me*. That meant the thing was getting out, even when it was flying at an angle of 35 to 45 degrees above the horizon. I used 12 radials laid under the snow, each ¼ wavelength long at 1.8 MHz. When W0AIH answered me during a run, I knew I was doing something right!

I noticed some static buildup on the antenna while it was being put up. This should be expected. Avoid shock by not touching the ground wire or lead-in before the antenna has been connected. If it snows or rains, or if the wind gets too strong, the antenna should be reeled in. It's no fun to work in constant fear of a sudden load change.

Trial and error is part of any project, but I hope this article will help you avoid some of the more common problems involved in trying to fly balloon-supported antennas. More complex projects, such as balloon-supported wire quads for 160 meters, are in the back of my mind.

Future Designs

The main problem was the wind. It is not common for many locations to be windless or near windless in the wintertime. A plain balloon will be blown down by a wind of more than about 20 miles per hour. Kites would be better under such conditions, but there is no guarantee that a kite will stay up when conditions change. It would be ideal to have a device that would fly under conditions of no wind up to perhaps 30 or even 35 miles per hour. (Wind speeds greater than 35 miles per hour are unfavorable even for the best kites.) I have heard that there is a device called a Kytoon that will serve this purpose, but I would prefer to attempt to build my own at low cost, since these flying machines seem to have a propensity for getting lost or destroyed.

The stabilizer described here is a big help, but in a gusty wind, or a wind more than 20 miles per hour, the balloon still flies very low and may hit tree branches, and get snagged, or pop. It may be necessary to use a kite for relatively windy conditions and a balloon for less windy weather, but the goal is to make a single device that will stay up in a variety of weather conditions. One idea is to attach a balloon to a small kite. In this case, it's important that the balloon be able to lift the kite, and that the kite not break because of the added wind resistance caused by the balloon. It should also be ensured that the balloon will not be popped by a pointed part of the kite. Figure 7A shows one possible arrangement.

Another idea is to use a pair of garbage bags for the balloon or, alternatively, large plastic bags from a department store. Two of the bags could be taped together using wide plastic tape, such as is shown in Figure 7B. The joint could be sealed with acrylic spray and the gas put in a hole cut in a corner of the bag. It is of a shape that might be rigged to fly as a kite, especially if fins could be attached for stabilization.

I plan to keep working on balloon supports that are more reliable and that will stay up longer. The low bands are primarily wintertime DX bands, which is fine since there are no thunderstorms in many places during the winter.

Conclusions

I thought about putting up some sort of short vertical or inverted L and forgetting about the balloon idea altogether. Such thoughts come to me when another balloon gets away—it is staggering to realize how many different ways this can happen—but nothing outperforms the ultimate, no-compromise, full-size antenna for transmitting. I'll keep the short verticals, longwires and inverted Ls for use when conditions will not permit balloon flying, but in the next 160-meter contest, you can be pretty sure that if W1GV has a big signal, the antenna is a ⅝-wave balloon vertical or a longer balloon sloper! 73