Balloon-lifted Full Wave Loop Antennas

Jim DeLoach, WU0I

ARRL The national association for AMATEUR RADIO

Why Balloon Lifted Antennas?

- Because they are a great way to experiment with really interesting antennas that just wouldn't fit at home
- Because they are a great way to achieve outstanding performance, particularly on the low-bands
- Because they are fun – particularly for Field Day!

ARRL The national association for AMATEUR RADIO

Introduction

- My amateur radio club* has been flying balloon-lifted antennas for years for Field Day and other contests, and you can too!
- This presentation:
  - Gives you the background you need to fly balloon-lifted antennas
  - Presents my design for a “Balloon-lifted Full Wave Loop Antenna” as published in the ***July 2007 QST***
  - Shares some important balloon safety tips

ARRL The national association for AMATEUR RADIO

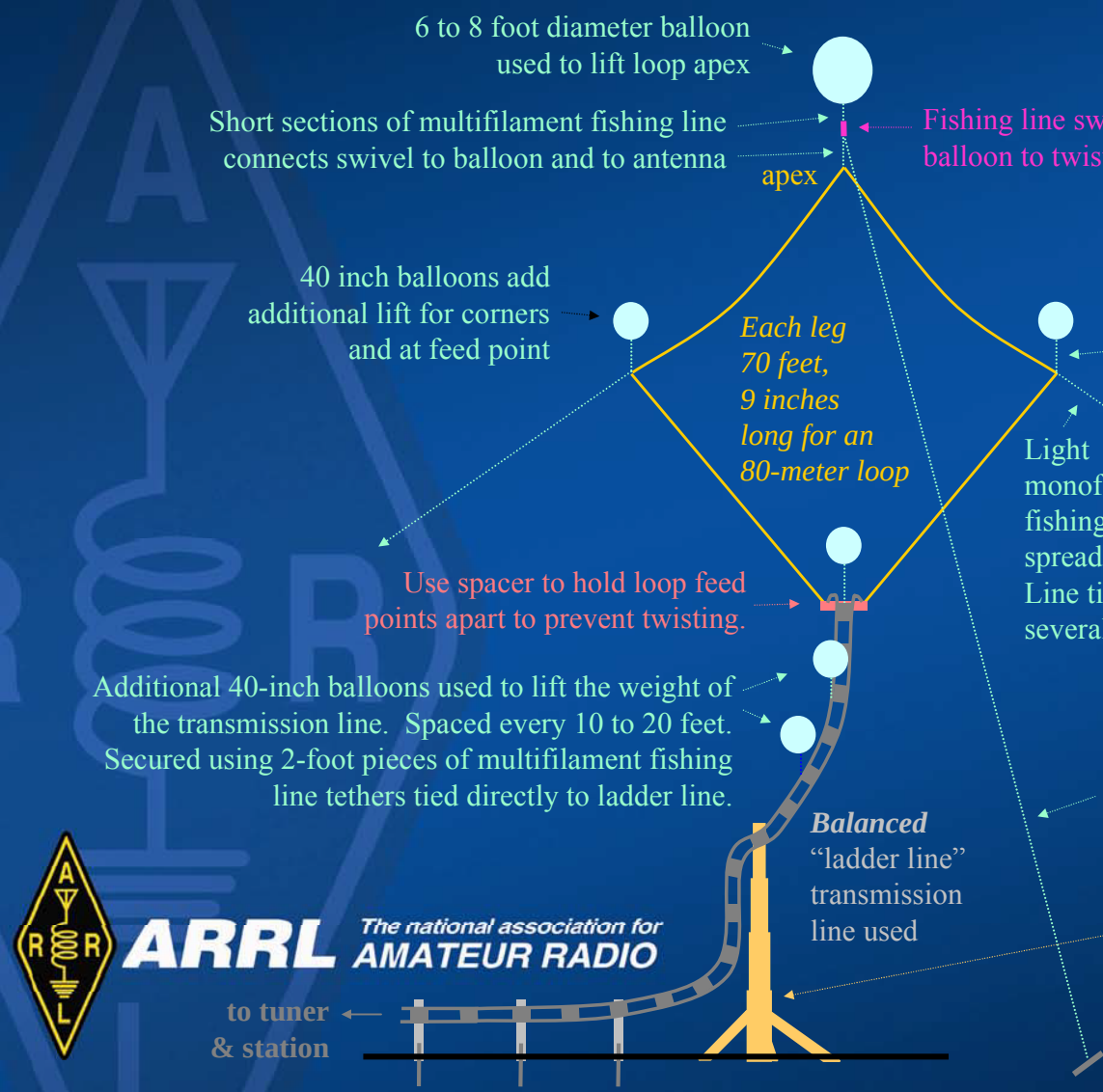
* The ESL Amateur Radio Club, Sunnyvale, California, in conjunction with the West Valley Amateur Radio Association, San Jose, California

Why a Full-wave Loop Instead of Some Other Antenna Design?

- Loops are balanced and don't require a ground plane
- Loops can be horizontally polarized, so they have less noise – a key advantage on the lower HF bands
- Loops perform well when low to the ground – much better at heights <1/4λ than any other balanced antenna type
- Loops are broad-banded, easier to tune, and far more likely to stay in tune as the antenna is blowing around in the wind
- A loop's radiation pattern is quite broad and thus remains consistent as the antenna shape, altitude, and orientation shifts in the wind
- Loops can be tuned to other bands and typically perform well on these bands
- Loops have good anti-static characteristics

ARRL The national association for AMATEUR RADIO

80-meter Balloon-lifted Full Wave Loop Design Overview



ARRL The national association for AMATEUR RADIO

Constructing the Loop

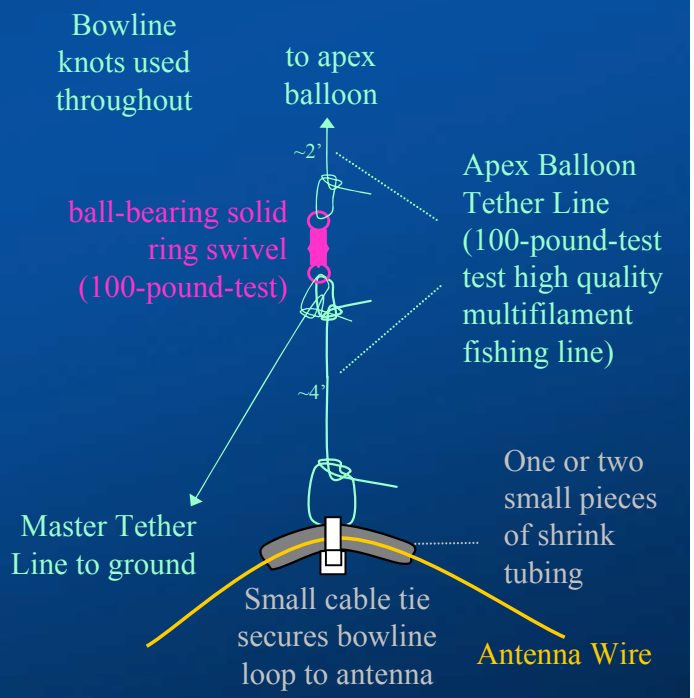
- The size of a full wave loop antenna is given by the ARRL Antenna Book as:

  Circumference (feet) = 1005/Frequency (Mhz)

- Use small, light wire to keep the loop's weight down (see Materials slide)
- Strip and tin about an inch from each end, if stranded wire is used.
- The fishing line tethers themselves serve as the insulators for this antenna, and these tethers are simply cable tied to the antenna wire during the lifting phase.
- To strain-relieve the loop wire at these tether points, pre-position one or two ~1-inch sections of shrink wrap at the top and side corners of the diamond, as shown in the apex & corner figures
- Feed one or two pieces of shrink tubing down the loop wire for each corner

ARRL The national association for AMATEUR RADIO

Apex Tether Detail

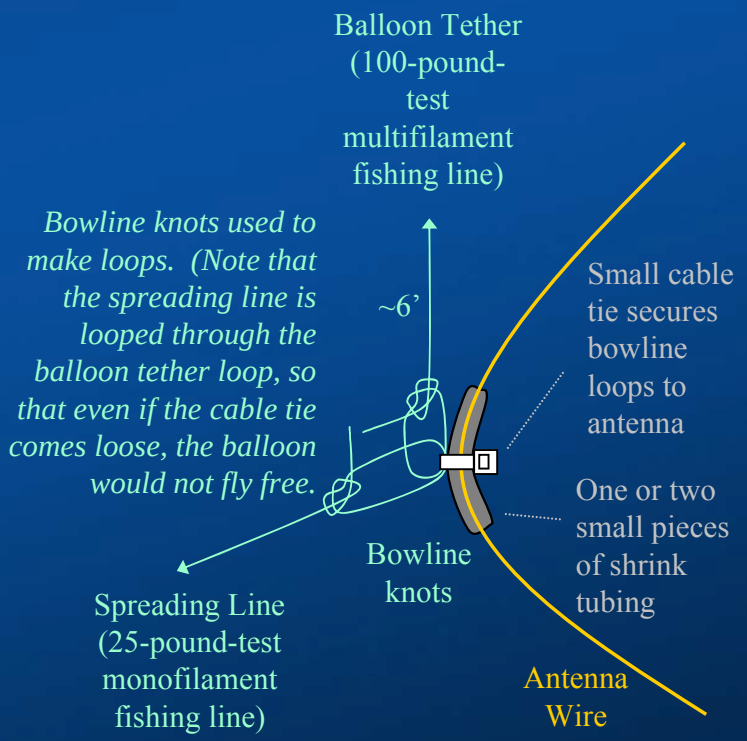


Constructing the Loop (continued)

- Gently fold the wire in half to identify the apex corner position (be careful not to kink or bend the wire!)
- Shrink the tubing at this halfway point (this is the apex corner)
- Again gently fold the antenna in to quarters to identify the side corner positions
- Shrink tubing at these two positions as well
- Spread the wire out again halved, with the two feed points side by side
- Roll up the loop wire, starting with the two feed ends
  - This will put the apex corner on the outside of the roll (which helps when deploying the antenna)
  - Be careful not to kink, bend, or knot the wire when rolling it up

ARRL The national association for AMATEUR RADIO

Corner Tether Detail



Preparing Balloons

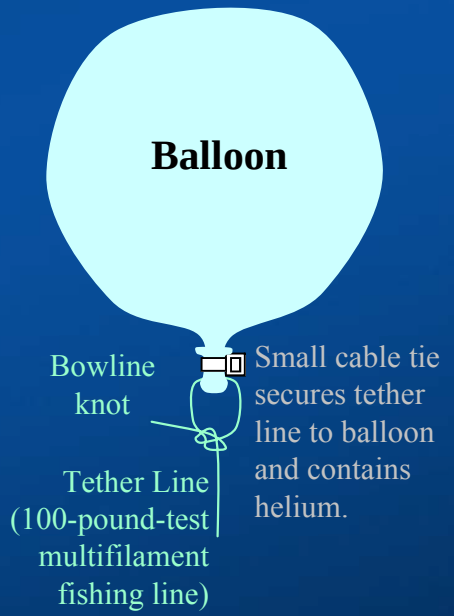
- My preference is to use one 5.5 to 6-foot balloon at the apex, along with several smaller 40 inch balloons at additional locations to lift the loop
- Use only helium gas to inflate balloons!
  - Hydrogen is explosive and not worth messing with!
- Before inflating balloons, prepare all tether lines.
  - Cut pieces of 100-pound-test multifilament fishing line to the lengths shown in the figures
  - Make a bowline knot with a loop at least as big as a fist on one end
  - Tie a simple slip knot on the other end to prevent unraveling
- Now inflate the balloons
- Have one person tightly hold the lip of the balloon over the tank nozzle while a second person carefully holds the tank steady and gently opens the valve
  - Have a third person judge the size of the balloon and warn the inflator when it is time to stop
  - Inflate balloons only to about 80% of rated size to allow for some expansion and to prevent popping
  - Keep in mind however that balloons pop! Always have spare balloons and helium to cover this eventuality

ARRL The national association for AMATEUR RADIO

Preparing Balloons (continued)

- Note that a crack in the nozzle assembly can cause the helium tank to become a dangerous projectile!
  - Any time the protective cover is off, be very careful not to let the tank fall, and consider securing the tank to a solid object
  - Keep the protective cover screwed on tightly when not inflating
- Once inflated, secure each balloon to a tether line
  - Fold the balloon neck over a bowline loop
  - Cinch a cable tie around both sides of the neck fold
  - Trim excess cable tie
- Tie each balloon to something solid until you are ready to lift the antenna
- After use, the cable tie can often be snipped off without damaging the balloon, but note that used balloons are far more prone to popping

Connecting Balloon to Tether Detail

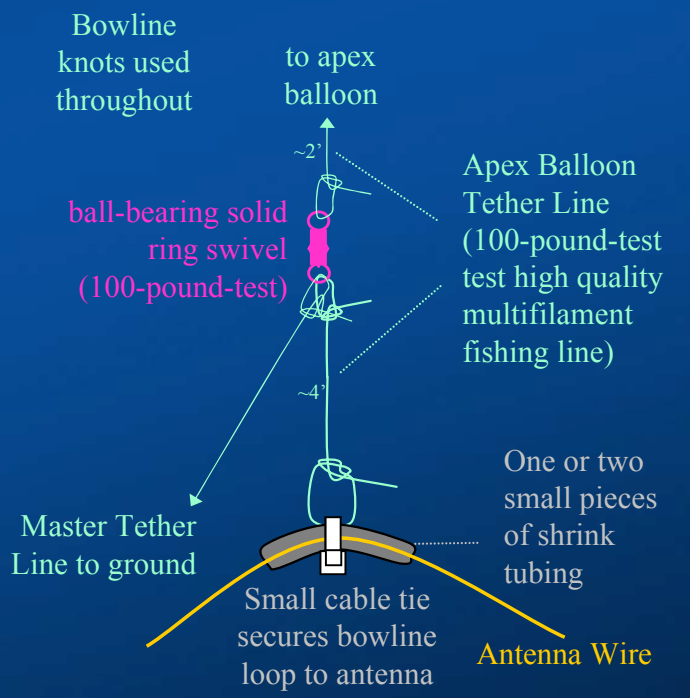


ARRL The national association for AMATEUR RADIO

Raising the Antenna

- Once all balloons are inflated and tethered, you are ready to launch your antenna
- Connect the large balloon to the antenna apex as shown
- Also tie the master tether line to the bottom of the swivel
  - The master tether line holds the apex balloon independent of the antenna, so it should be kept clear of the antenna wiring and tether lines.
  - Typically this means that it is secured a little upwind of the antenna.
- Use Bowline knots throughout
- Let the apex balloon slowly rise upward as you unwind the antenna wire and the master tether
- Be careful not to allow the two antenna wires to kink or knot, or to tangle with the master tether

Apex Tether Detail



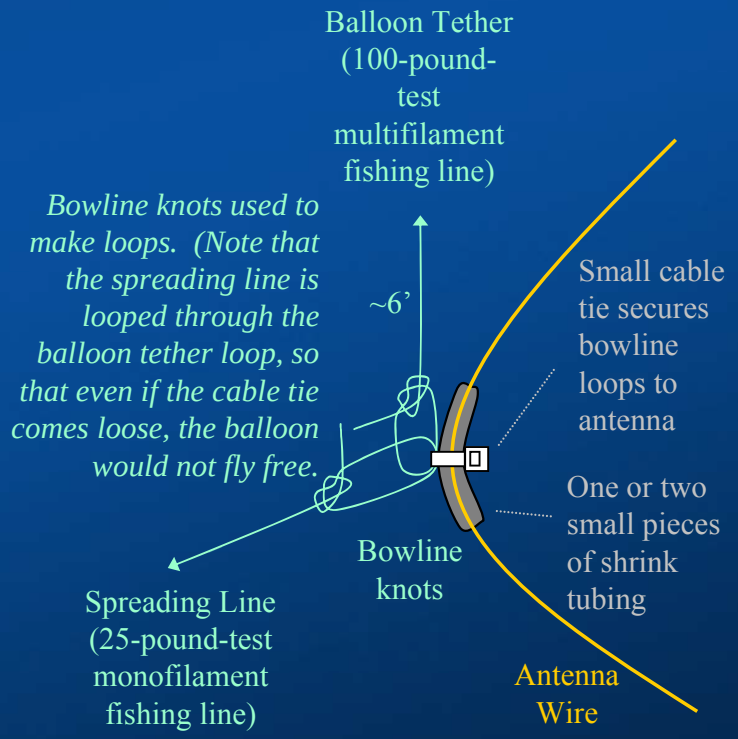
ARRL The national association for AMATEUR RADIO

Raising the Antenna (continued)

- Continue to unwind the antenna wire and master tether until you reach the corner tether points
- Secure the spreading lines and additional balloons to each corner
- Spreading lines pull the diamond apart, and they work best if they are very light (25-pound-test monofilament fishing line works well)
- Optionally tie colorful flag tape to the bowline loops to improve corner visibility once the antenna is lifted
- Continue to unwind the antenna wire, master tether, and two spreading lines while walking the spreading lines apart until you reach the ends of the loop antenna wires

ARRL The national association for AMATEUR RADIO

Corner Tether Detail



Balloon Lift

- Balloon lift is a function of size, weight, material type, altitude, pressure, and temperature
- Lift predictions have been published (see “Links” slide), but in my experience, lift never quite matches up to predicted values
  - Probably at least partially because I never inflate balloons to their fully rated diameter to allow for expansion
- The typical lift I seem to get is shown in the table
- Your experience may vary, particularly at different altitudes

Balloon Diameter	Typical Lift I Get
40”	~1 lb
5.5-6’	~3-5 lbs
8’	~10-15 lbs

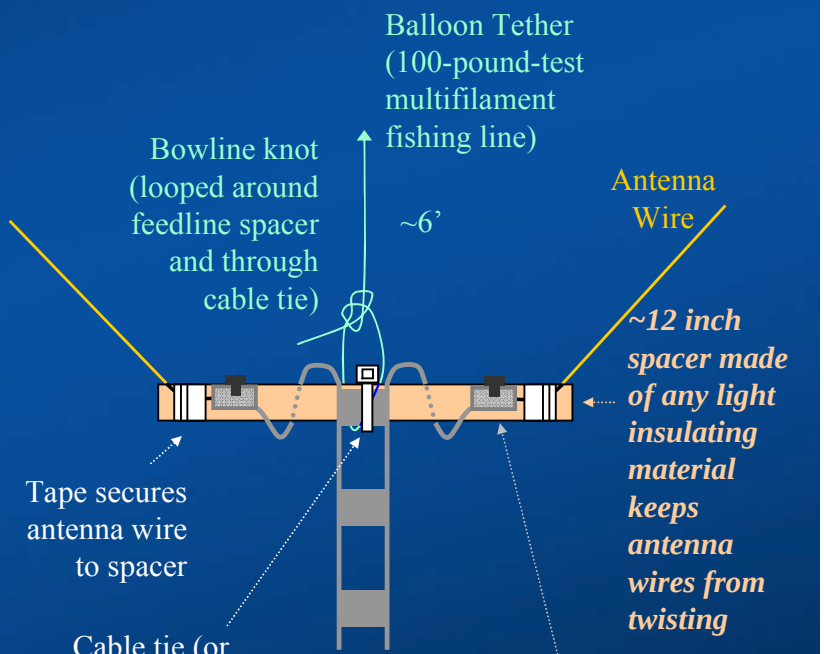
ARRL The national association for AMATEUR RADIO

Secure Feed Line

- A spacer is essential to prevent the feed wires from twisting and potentially shorting out
- Use any convenient light, nonconductive material about 12 inches long
  - I have used sticks, school rulers, and just about anything handy
- Cable tie ladder-line to spacer and balloon tether as shown
- Connect transmission line to antenna wires using screw compression type wire connectors or some other form or wire connectors (see Materials slide)
- Strain-relieve antenna wires to spacer using electrical tape.
- Reel out feed line, tying on a 40-inch balloon every 10 to 20 feet
- Once antenna is in position, experiment with tether and spreading line lengths to get loop to take on as close to a diamond shape as possible

ARRL The national association for AMATEUR RADIO

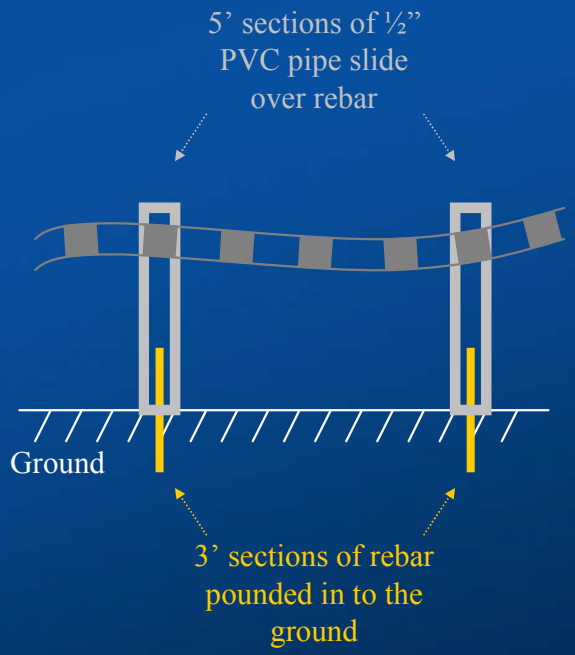
Feed Point Detail



Transmission Line

- Used balanced “ladder” transmission line
  - Far more efficient than coax
  - Tunes much easier
  - A great choice for temporary operations
- Transmission line needs to be kept away from metal objects and can not run along the ground
- Jim, K6EI, came up with a great way to further distribute the transmission line for Field Day, using PVC pipe and small sections of rebar
  - Pound 3-foot sections of rebar in the ground
  - slip 5-foot sections of ½-inch PVC pipe over the rebar
  - Tape the transmission line to the top of the PVC
  - Space pipes every 10 or 15 feet to the balanced tuner

The K6EI Balanced Transmission Line Distribution Method



ARRL The national association for AMATEUR RADIO

Static Build-up

- Wind-induced static build-up has been reported for large balloon-lifted monopole antennas
- Since loops present a short at DC, differential mode voltage build-up will not occur
  - However, common-mode build up is possible
- We have never experienced this phenomenon, perhaps because we are in a low static area, but if you do, connect two 1MΩ, high wattage, non-inductive resistors between the tuner's balanced antenna terminals and ground to bleed off the static charge

ARRL The national association for AMATEUR RADIO

Performance

- So how well do these antennas work?
  - Jim, K6EI, recalls creating a pile-up after calling CQ, holding a frequency through the contest, and even working Japan – all on 80 meters while running 5 watts!
  - Greg, N6GD, reports that “on 80 CW, there wasn't anybody I heard that I couldn't work with the loop. Pretty amazing considering we were running only 5 watts!”
- These comments are typical. Our field day experience has always been that if the balloons stay up, the antenna rocks, even running QRP!

ARRL The national association for AMATEUR RADIO

Wind

- Wind is the big limitation with balloon-lifted antennas
- The simple reality is that balloon-lifted antennas will only survive and perform well in light to moderate winds
- What we do is use our balloon-lifted antennas ***at the times of day when the winds are low***
  - At our Field Day site, the winds subside about dusk, and pick up by mid-afternoon, so we put up the 80-loop right after dinner on Saturday
  - Two Field Days out of three, it survives till 80-meters shuts down Sunday morning!

ARRL The national association for AMATEUR RADIO

Safety Precautions

1. Make sure you have plenty of space! Never fly a balloon antenna where it could possibly come down on a power line, any other wire, any structure, roads, or rail lines.
2. Fly balloon antennas only in light to moderate winds. Pull the antenna down when winds rise, and wait for the winds to subside.
3. Use tether lines sizes appropriate for the possible wind load. Do not used frayed or damaged tether lines.
4. Wear gloves when handling tethers or antenna wire.
5. Never fly a balloon antenna in a thunder storm!
6. Inflate with Helium only!
7. Always tether the balloon to the ground with a line separate from the antenna support structure. Tether lines should be stronger than balloons. Use good knots like the bowline.
8. Be careful with helium tanks. When transporting, secure tanks so that they can not role around in a vehicle. Tanks are heavy, so always have enough people around when lifting. Always keep the valve closed and the nozzle cover secured when not actually inflating balloons. Never let tanks fall – particularly when the nozzle is exposed!

ARRL The national association for AMATEUR RADIO

FAA “Moored Balloon” Regulations

- In the US, the Federal Aviation Administration (FAA) defines regulations governing the operation of moored balloons (see “Links” Slide below)
- A moored balloon is exempt from these regulations as long as it is not operated “in a manner that creates a hazard to other persons or their property”, it is not more than then 6 feet in diameter, and its gas capacity is not greater than 115 cubic feet
- Larger balloons must comply with additional requirements:
  - The nearest airport must not be within 5 miles.
  - Ground visibility must be 3 miles or more.
  - Balloons must be at least 500 feet below the base of any cloud.
  - An automatic deflation mechanism must deflate the balloon should it escape.
- Operation at heights greater than 150 feet trigger onerous additional advanced notification, lighting, and visual warning requirements, and operation above 500 feet is banned outright
- Keeping balloon size to 6 feet in diameter or less is clearly the easiest way to comply with FAA regulations
- If larger balloons are desired, as long as total height is restricted to 150 feet, these requirements are not too onerous – the weather just has to be good, and the site has to be at least 5 miles away from the nearest airport

ARRL The national association for AMATEUR RADIO

Links

- I keep a list of balloon-lifted antenna links (including the links below) at: www.deloach.net/balloons
- The University of Hawaii has an excellent web site discussing balloon buoyancy, balloon materials, and antenna construction materials at: www.chem.hawaii.edu/uham/lift.html
- Another easy to read discussion of helium buoyancy can be found at: www.howstuffworks.com/helium1.htm
- See www.tollesburysc.co.uk/Knots/Bowline.htm for an illustrated example of the Bowline knot
- Federal Aviation Administration regulations concerning “moored balloons” can be found in the Electronic Code of Federal Regulations (e-FCR), Part 101 – “Moored Balloons, Kites, Unmanned Rockets and Unmanned Free Balloons”, at the following URL: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=137a53aeac5e065fd3dd16bdc30ecb17&rgn=div5&view=text&node=14:2.0.1.3.15&idno=14

ARRL The national association for AMATEUR RADIO

Materials

antenna wire	I use surplus stranded 22-gauge wire from Fair Radio Sales. Part number SEB-400X3, 306' spool for $12.95. www.fairradio.com/. Other authors suggest using "fine aluminum welding wire" from welding shops.
Helium	Helium can be purchased, from local party balloon suppliers (I use www.peoplegreeters.com), industrial gas, or welding supply shops. Note that costs have increased recently due to a helium shortage. Tank sizes vary widely. I use 176 ft^3 tanks that weigh 80 pounds. I have never needed a regulator given the types of tanks I use, but check with your supplier. Balloon volume is given by $(4/3)*\pi*(\text{diameter}/2)^3$, but I typically only inflate to 80% of balloon capacity. Thus a 40" balloon needs 15.5 ft^3 and a 6' balloon needs 90.5 ft^3. If one 6' and five 40" balloons are desired, and you want to have double the helium just in case, then you need 336 ft^3. I typically get 2 176 ft^3 tanks.
Balloons	I use latex or chloroprene "car dealer" balloons from my local helium source, the web (e.g. www.balloonlovers.com) or eBay.) 40" balloons are $2.50, ~6' balloons are $18. Balloons last longest when stored in a cool, dark place. If you have several hundred dollars to spend and want to get serious, a heavy-duty vinyl advertising balloon will last for years, and you can put your club logo on it! Note that you will need to use much larger tether rope than discussed in this article. Place a drop cloth under vinyl balloons when inflating. Avoid surplus weather balloons, as they tend to be fragile and pop easily when moored.

ARRL The national association for AMATEUR RADIO

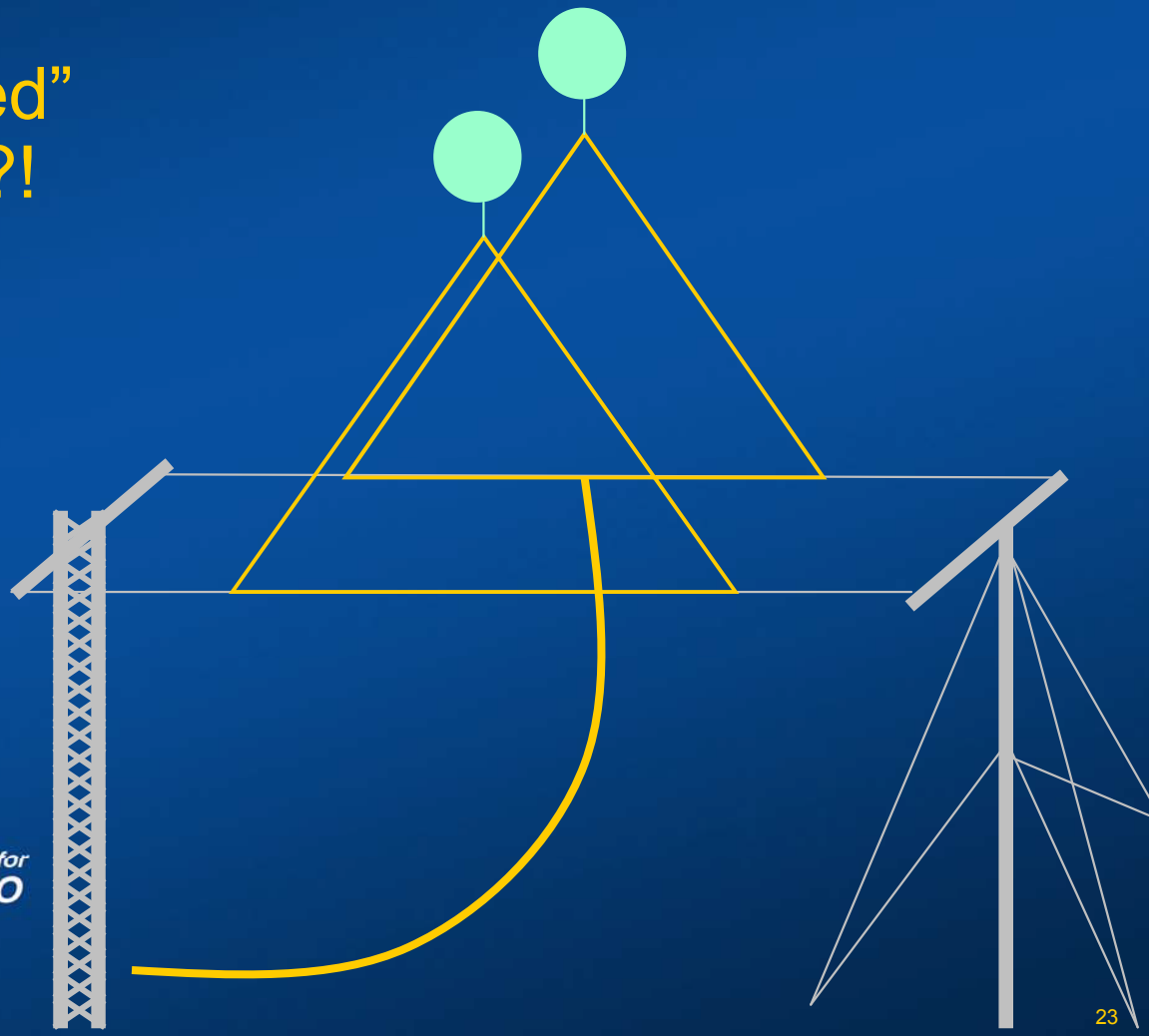
Materials (continued)

nonconductive mast	The MFJ-1910 fiberglass mast www.mfjenterprises.com works well for this purpose. Cost: $80. High voltage "hot sticks" also work. I have used the tripod from an AS-2236 militlog-periodic antenna to hold the mast.
Wire connectors	Screw compression type wire connectors taken from small mechanical lugs (i.e. http://www.doityourself.com/invt/8017337) work well for me. Alternatively, use small "cap" style wire connectors or crimp butt splitters. Source: any hardware store. Cost: a few dollars.
tether line & swivels	100-pound-test tether lines are sufficient for balloons up to 6 feet in diameter. Any fishing store can sell monofilament line, multifilament line, and swivels. Total cost: about $20.
Tuners	*Use only a tuner made for balanced lines!* Others *do not work*. The MFJ-974HB ($190.) www.mfjenterprises.com and old Johnson Matchbox tuners work well.
Static bleed-off resistors	1MΩ or more, non-inductive power resistors rated for over 2 watts should do for up to 100 Watts radiated power (i.e. Digikey PPC1.0MW-3JCT-ND).

ARRL The national association for AMATEUR RADIO

Other Balloon-lifted Antenna Ideas

- How about a "Balloon Assisted" 40-meter Quad?!



ARRL The national association for AMATEUR RADIO

Conclusion

- Balloon-lifted antennas are only limited by your imagination!
- So for your next Field Day or other remote contest event, give a balloon-lifted antenna a try!
- See what it's like to have the big signal!

ARRL The national association for AMATEUR RADIO

Questions?

ARRL The national association for AMATEUR RADIO