Antennas for Aircraft

by

Bob Archer

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TENNA TIP # 1

COM ANTENNAS FOR COMPOSITE AIRCRAFT

by Bob Archer of Sportcraft Antennas

The art of installing antennas internally into composite aircraft has left many people confused and perplexed so I have decided to try to give some tips and information on the subject. Some people have tried to install monopole antennas internally with a ground plane installed for the antenna to work against and this is just totally bad. To work properly a ground plane should be at least a half wavelength in diameter and at VHF frequencies this is about four feet. Needless to say there is no place this large to put a ground plane on a small composite aircraft.

First of all I believe that only dipole type antennas should be used in composite (non-conductive) aircraft and that the best location for COM antennas is in the vertical stabilizer while the second best is in the fuselage tailcone. The reason being that COM antennas are vertically polarized and therefore require a vertical space of about 46" for a half wave dipole. The larger aircraft have enough height for an aperture of a full half wavelength but the smaller types need an antenna that is shortened a bit. Think of aperture as the capture area of an antenna. Mounted high in the vertical tail the antenna is high enough to see all the way around while the fuselage mounted antenna may suffer some signal loss due to blockage from engine, passengers, and miscellaneous "stuff". The SA-006 COMM antenna was designed to replace some very bad antennas that were sold in the early days to two place composite builders. It is constructed of .016 inch 2024 Alclad aluminum so that it can conform to the inside curvature of the fuselage and is 26 inches high by 12 inches fore and aft. After the tail is sealed up of course it is very difficult to replace the tail antenna so this antenna was made as a replacement. This antenna was test flown mounted in the fuselage of the LANCAIR 320 prototype aircraft and a transmission was received from an aircraft at a distance of about 170 miles.

The SA-008 COMM antenna is designed for installation in aircraft with larger vertical tails such as the Lancair IV, Glasair, Express and the many versions of Ex’s. This dipole antenna is a full half wavelength which provides the maximum aperture at this frequency. This antenna is shipped with the elements folded up so the elements must be unfolded and adjusted in sweep to fit into the available space in the Vert. stab., riveted in this configuration and then bonded in. Remember that graphite composite material is conductive so it must be treated as if it were metal. This means that on the Lancair IV, the only place to install internal antennas is inside the fiber glass wingtips, the dorsal / vertical stabilizer and perhaps the Plexiglas windows.

Graphite structures do complicate matters for antenna installations. If spar caps are constructed of graphite materials horizontally polarized antennas should not be mounted nearby because practically no signal will be able to get past the long conductors that will act as reflectors. The same goes for any long conductors in the same alignment as the antenna such as horizontal and vertical tail spars, control cables, push rods, wires etc. Each aircraft needs to be analyzed individually for the best antenna locations.

I do not recommend any antenna on the market that has a little black box in the center of the antenna. This device is a ferrite transformer which provides a very good VSWR and a very good bandwidth but at the cost of being a very lossy (absorbs energy)device. The very best specification that I have seen on ferrite transformers is a loss of 2.5 dB and the worst goes up to 12 dB. As a reference, a 3-dB loss gives an output of 50% and 10 dB gives just 10% out. So if you have a 5 watt transmitter into an antenna like this, you get just .5 watt out, and it works the same on receiving. Not a bargain. An antenna you can easily make yourself would be to just solder quarter wave elements to the inner and outer conductors of the coaxial cable and go with it. Also if you were planning to go with Jim Weir of RST's designs don't bother with the ferrite beads. At these frequencies the beads don't do anything that I could detect in the RF lab. A good balun would work better as a dipole feed because it balances the currents on the elements and matches the impedance at the same time and it doesn't absorb RF energy. My antenna designs do not need a balun because I use a modified version of a feed called a Gamma match that feeds the antenna at the fifty-ohm point and automatically balances the currents on the elements.

When installing any antenna remember that antennas do interfere with each other when installed too close together and that close metallic (or conductive : remember graphite) objects that are as long or longer in the same polarization/plane will reflect RF energy away from them. Close meaning one wavelength or closer and closer being worse. One wavelength is about eight feet at VHF frequencies. Less than a quarter wavelength is really bad from both a VSWR and the radiation pattern standpoint. The formula for wavelength is: 11803/ FREQ. in Mhz. = wavelength in inches.

So there being only one good location for an internal COMM antenna (unless you have twin verticals) and antennas don't work well close together, it follows that for aircraft with dual transceivers and no good location for a second antenna there is a need for a two set switching device of some type. I recommend a RF switch, single pole double throw type. A switch like this will allow you to receive and transmit on a single frequency and when switching from one set to the other, the switch will connect the proper set to the antenna. This type of switch is available from ham radio outlets. Another type of switch that allows receiving on two sets at the same time while transmitting straight to the antenna is now available due to popular demand from Sportcraft Antennas.

After you airplane is flying it would be a good idea to check the radiation pattern for holes or nulls. A good way of doing this would be to climb to about 5000 feet at fifty miles or so from an airport with an atis and fly flat circles while listening to the signal strength. After a few turns you should be aware of the directions of the weak or non existent signal reception. This works better than field strength meter on the ground.

These suggestions and recommendations come from 35 years of spacecraft and aircraft antenna experience and are meant to help in obtaining optimum antenna performance and do not mean that anything else will not "work". I have seen a lot of really bad antenna installations whose owners are perfectly happy with their antenna performance.

I will address some other antenna installation problem areas in the future.

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Below are frequently used antenna terms and with short definitions .

- **Active Elements?** The part of the antenna that actually does the radiating or the receiving of the RF energy.
- **Aperture?** The capture area of the antenna. On a dipole or monopole it is the overall dimension of the active elements, on dish antennas it is the diameter of the dish.
- **Feed point?** Generally the point at which the coaxial cable attaches to the antenna but could be where the feed device attaches to the active elements
- **VSWR? Voltage Standing Wave Ratio.** The measurement of the ratio of incident to reflected RF energy. An indication of the quality of energy transference. The lower the number the better. 1:1 is perfect. 2:1 is good ,3:1 is OK, 4:1 and up is poor to terrible.

- **Radiation Pattern?** A pattern showing the relative signal level around an antenna. Signal strength can be severely reduced in particular directions by other antennas, vertical stabilizers**,** landing gears etc.
- **Balun?** A device that converts a balanced transmission line (such as TV twin lead) to a coaxial line which is an unbalanced line. Provides balanced currents on dipole antennas while matching the 50-ohm line to the nominally 150-ohm antenna.

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Navigation antennas being horizontally polarized require that they be mounted in an area that has a large enough horizontal area that a half wave dipole can be installed. If the elements are swept the dipole can be reduced to about 40 inches. The logical locations are the wings, horizontal stabilizer and the top and bottom of the fuselage. There are always gotchas though and wings with large conductive horizontal structures such as graphite wing spar caps, push rods, cables etc. are not ideal locations. If the antennas in such wings can be positioned so that they are about 0.2 wave lengths (about 20 inches) ahead of the spars or such they would have more gain from the front but would reduce signals from the rear. If mounted behind the spar or other conductive device the reverse would be true and the signal would be stronger from the rear.

If the horizontal tail is constructed of graphite of course it is not suitable for antenna installations. Other than that it is a pretty good location except in the case where the signal is coming from directly in front and has to pass through the engine and cabin area to arrive at the antenna. If the aircraft is a canard of course the reverse is true. In this condition the signal will be weakened and the CDI needle could possibly wander. This also happens in the case of a metal aircraft with the VOR antenna on the top of the vertical stabilizer. When the airframe gets between the transmit and receive antennas as you approach the VOR station there is usually a bit of needle wagging going on.

In the case of aircraft with almost all graphite construction and graphite being conductive the only location for internally mounted VOR antennas would be in the fiber glass wing tips. Because of the wing tip lights, wires and strobes normal types of antennas work very poorly in this location. The light wires have a very low impedance to ground and being so close to the antenna tend to short the RF energy to ground. To solve this problem I have developed a series of wing tip VOR antennas that are shorted to ground DC wise and are very good antennas RF wise. These antennas are grounded monopoles fed with a modified gamma match and the parameters are such that the VSRW matches well across the VOR frequency band. The wing tip lights and wires on these antennas become part of the antenna and therefore have no effect on the antenna performance. Antennas of these types have been flown for years on various types of aircraft with excellent results. If your installation has two VOR antennas do not connect them together using any means unless you really, really know what you are doing. Being as far apart as the wing tips are will cause a phasing problem between the antennas that causes multiple lobes to be formed, the number of lobes being determined by the distance apart. Using one antenna for each receiver will result in the increase in range of about 25% over one antenna with a two set coupler into two receivers. Try to keep at least a 2" radius on all RG58/U cable installations. The same things apply to VOR antennas that I mentioned last time such as little black ferrite transformer boxes and ferrite beads. I don't believe that ferrite devices have any place in antennas because they do absorb RF energy.

Just a few words on dipole antennas for clarification. There are two types of dipoles, the two element type that is fed in the center, and is the type that is common and everyone is familiar with. There is also a continuous conductor type that is a continuous conductor from tip to tip for a full half wavelength. Each of these types require a different type of feed device. A center fed dipole dipole really should have a balun installed for proper operation. Without a balun on a center fed dipole fed with coaxial cable the antenna has uneven currents on the elements because half the currents on the braid side travel down the outside of the cable, the impedance is poor because the nominal impedance of this type of dipole is 150 ohms and is being fed with 50 ohm cable and the radiation pattern is bad because the radiation off the outside of the outer conductor interferes with the radiation off the elements. So a good balun does three things:

1. Balances the currents on the elements.
2. Matches the impedance of the cable to the elements.
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For those that would rather do it themselves I have enclosed a rather rough sketch of a modified type two balun, I believe it is, that very neatly solves these problems. I recommend using RG142/U cable if available for its resistance to melting during soldering. By the way those ferrite beads that so many composite builders are using are totally useless. The beads do absolutely nothing at these frequencies that I could determine. And the ones with the ferrite transformers in the center are very lossy. Up to 12 dB depending on the type they are using. I strongly recommend using a real balun.

The continuous conductor dipole is interesting in that the center point has an impedance of zero ohms and the tips have an impedance of infinity, or there abouts, so somewhere between zero and infinity there is bound to be an impedance point that we could use. If we were to split the conductors apart on a 300 ohm twin lead cable and attach a conductor to the 150 ohm point on each side of the neutral center we would have a very good 300 ohm antenna. To feed with a 50 ohm cable though is a bit more of a problem. What we need to do here is to connect the braid of the cable to the neutral center point and the center conductor to the 50 ohm point on one side. A problem arises in that in connecting the center conductor to the antenna element we introduce an inductive loop which needs to be balanced out with a series capacitance. When all the parameters are correct this also becomes a very good antenna. This antenna design allows control of the length, feed point impedance and capacitance/inductance relationships so can be tuned to a high level of performance. Specialized antenna measuring equipment must be used for tuning this type of antenna. Most of my antennas are designed in this manner.

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Polarization? The plane in which RF energy is radiated. Normally either vertical, such as COM, or horizontal, such as VOR, or any angle in between, such as bent COM antennas. There is also circular polarization, which we will discuss along with GPS antennas.

TENNA TIP #3

GPS Antennas for All Types of Aircraft

by

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Because there seems to be at present more interest in GPS than any other aircraft system I think we should talk about it first. The theory of how GPS operates is very similar to Loran in that it uses the time difference between three or four transmitted pulse strings from three or four sources to determine Hyperbolic equal time difference lines and calculates position from this data. Of course space based transmitters transmit the GPS signals and Loran transmitters are land based. And the frequencies of operation are very different, the Loran systems operating at 100 Kilohertz and GPS at 1.575 Gigahertz, with a secondary frequency at 1.227 Ghz. A wavelength at 100 Khz. is 9836 ft. and at 1.575 Ghz. is about 7.5 inches. These wavelengths give an indication of the size of the required antennas; a large antenna for Loran, a small one for GPS. About 3 3/4 inches for a dipole. There is a galaxy of 24 GPS satellites now in earth orbit at an altitude of about 10,600 miles which gives them an orbit period of about 12 hours. Their calibrations are updated as to time and position every orbit to maintain their accuracy.

Most satellite systems, including GPS, use circular polarization for their RF systems which means that the electric field rotates at the rate of the frequency being used. You might think of it as 360 degrees of polarization rotation in one wavelength of travel. Circular polarization is used because linear polarization when passing through the heavyside layer of the upper atmosphere rotates the polarization depending on the angle of passage and it is possible for the signal to completely cancel out. When using circular polarization on both transmitter and receiver antennas these effects are minimized and maximum signal may be utilized. Of course both ends must use the same rotation, either RH or LH circular polarization, or the signals could cancel out.

There are several different types of receiving antennas that can be used by GPS receivers and I'll try to touch on each of them. All GPS receiving antennas should have a radiation pattern that optimally would look like a flattened hemisphere so that there is somewhat more gain at the low elevation angles because that is where the satellites are the farthest away. The first and most common at this time is the patch antenna. It is small and flat and can be installed easily on the outside of metal or graphite aircraft skins and inside of non-conductive composite aircraft with some minimum type of mounting bracket. Also there is what is called a turnstile antenna which consists of four small pieces of flat metal in a square pattern and each piece fed with 0,90,180 and 270 degrees of sequentially phased signal that provide the circular polarization. This type antenna is usually somewhat short on gain because of being loaded with dielectric material to make it small and having a quadrature hybrid of some type to provide the phased signals which will absorb some signal. A lot of these have built in amplifiers and they are then called "active" antennas.

Another type is the normal mode helix antenna. Garmin used these on their early models and still do on their handhelds and are about .75 inch in diameter and three inches long. A regular helix antenna radiates most energy off the end but a normal mode helix is smaller in diameter and radiates more energy off the sides. With the correct ratio of length to diameter the radiation pattern can be optimized. I have one of the Garmin handhelds and I wanted to put an antenna between the headliner and the fabric over the cabin of my Bellanca so I built a foam conical form two inches high by two inches in diameter and wound on extra long dipole type elements that wind down from the apex to the base in a spiral manner. Works very well. Then there are Archimedean spirals, log conical spirals and bifilar and quadrifilar helices and numerous turnstile types. All of which are circularly polarized with various positive and negative attributes.

The installation of all these types of antennas in a non-conductive composite aircraft, or even fabric, is simple in that none of them require ground planes and they are so small and light that they do not require much room or structure to support them. All that is required is that they be mounted in the top part of the aircraft looking up in such a manner that they can see most of the sky through the non-conductive skin when installed. In metal or conductive aircraft of course they must be installed on outside of the conductive skin of the aircraft or installed inside a fiber-glass fairing of some type. On tandem type aircraft with canopies the top of the roll over structure is a great location. We will just leave the details to the builders.

To test the reception of signal through glass or other types of skins just fire up the old hand held GPS out side the airplane and then take it inside and check the signal strength difference. There should be very little to no difference for glass, wood or fabric but graphite will cut the signal off. In my meanderings I have come across some primers that are heavily loadede with zinc chromate and such for fiber glass that are very lossy.

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TENNA TIP #4

Transponder Antennas for Composite Aircraft

Transponder systems are a direct descendant of the IFF (Identification Friend or Foe) systems that were developed during WWII to identify the friendlies. In operation the radar site transmits a pulse string in the same direction as the radar pulse, the transponder receiver in the airplane receives the pulse string, decodes it, encodes it with the airplanes code and retransmits the encoded pulse string back to the radar site. The receiver at the radar site decodes the pulse string and sends the signals off to the computer (in olden times straight to the scope) for enhancement etc. and thence on to the radar operator's scope. DME does pretty much the same thing in reverse with the aircraft's DME transmitter triggering the transponder at the radar site. Transponders operate at a frequency of 1030 and 1090 Mhz. and therefore a wave- length is about 11.5 inches. DME uses a bit more bandwidth and goes from 960 to 1215 Mhz. though the design center frequency is about the same and the same antenna can be used for both devices interchangeably. Most people these days would opt for GPS instead of DME because it does so much more so much better.

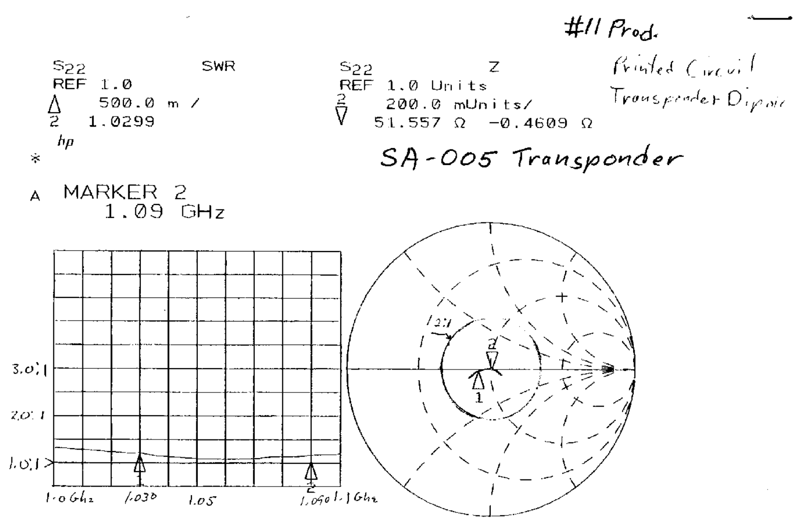
A composite builder has the option, unless it is graphite, of either installing a 1/4- wave monopole antenna, either internal or external or a 1/2- wave internal dipole antenna. If the option is for the external monopole a ground plane would be required and I would recommend about a 12 inch Al., or perhaps graphite, sheet attached to the outside bottom skin of the fuselage with the antenna mounted in the center. I would not recommend putting the ground plane on the inside with the antenna element extending through the skin of the aircraft. There can be strange effects with the signal going half through and half not through the thickness of the skin. In my experience installing any kind of mesh and trying to get and keep a positive RF ground connection between the cable shield and the mesh and can be a very iffy proposition. I have seen quite a few really BAD installations of this type. If the option is for an internally mounted 1/4- wave monopole the situation is even worse. I have seen drawings showing both seat bottom and wing- tip installations and neither is anything that I could recommend. The wing tip is bad because the polarization is supposed to be vertical and the wing tip is not thick enough so the monopole must be tipped about 45 degrees which causes a half power polarization loss and the ground plane installation cannot be horizontal or large enough so there is more loss. Also if you bank your airplane in the proper direction (or improper depending on your view) you could get a perfect cross polarization effect that would transfer no energy between antennas. The under the seat location is bad because there is so much "stuff" surrounding it and the large metal lump called the engine, not to mention the firewall, causing signal blockage from the front. I have heard numerous horror stories on the results of really bad installations. Conductive aircraft of course must have their antennas installed externally using the airframe as the ground plane.

My recommendation would be to install a Dipole antenna which does not require a ground plane though it would be about 6 inches in the vertical plane. The preferred locations would be out in the wing towards the tip if the wing is deep enough or as far back in the bottom of the tail cone as you could get it or in a ventral fin if you have one.

These equipments operate at a frequency approaching 10 times the frequency of aircraft VOR and COM systems with an accompanying increase in cable losses. This being the case a better cable than RG 58 is recommended for cables over about six to ten feet in length though a better antenna does help with less antenna loss. RG55/CU is the same as RG58 except it is double shielded and therefor has a bit less loss. RG142 is a very good double shielded Teflon cable with about 10% less loss than RG58 though it does cost quite a bit more. In general larger diameter cable such as RG 213 and RG 214 has less loss but is heavier and connectors are more expensive. Also RG 400 is double shielded.

The Sportcraft Antennas model SA-005 Transponder antenna is made from copper clad epoxy printed circuit board that has the antenna etched out of the copper to form a dipole antenna and an included etched in copper tapered balun. This antenna is 6" by 7" by .060" thick and the VSWR performance is so good as to be almost unbelievable. I have had numerous reports from customers describing the superior performance that these antennas have provided. One customer claimed a two radar sector increase in range.

Fig.1 shows the VSWR on a rectangular VSWR vs FREQ. chart and a Smith chart impedance plot.



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TENNA TIP #5

Electrical Noise & RF Interference in Aircraft

Over the years I have been getting more and more reports of people having problems with RF interference and aircraft electrical noise. RF interference manifests itself in strange happenings when the transmitter is keyed such as auto pilots flipping the airplane on its back, or trying to, instrument needles going to full scale or zero, blanking out LCD displays, and even turning ELTs on and in extreme cases blowing out the final amplifiers in the transmitter. Such goings on can be disconcerting to say the least. These types of problems are becoming more common with the advent all of these low voltage instrumentation devices that use liquid crystal and LED displays.Most of these problems are caused by antennas with high VSWR (Voltage Standing Wave Ratio) which many people have installed in their airplanes in the past. VSWR is an indicator of the amount of impedance mismatch at the antenna. When there is a mismatch the VSWR controls the amount of energy reflected back down the cable both on the inside and outside of the outer conductor of the coaxial cable. If the antenna has a good RF choke built into the antenna all the reflected energy would be not be forced to back down the inside of the cable otherwise some of it, maybe most of it, would be reflected and return down the outside of the cable to the transmitter area and radiating energy all the way. This radiated energy would be transmitted into every bit of metal within sight as well as combining with the energy radiated from the antenna causing ripples and peaks and nulls in the radiation pattern. It also gets into electronic equipment as mentioned above and can cause the electronic gremlins. The energy reflected back down the inside of the coax cable is another story. Most modern transmitters have safety devices built in but it is possible that if the power level of the reflected energy is high enough the transmitter could be damaged or destroyed. It depends on both the amplitude and the phase and if the phase of the peak voltages coincide the voltage could theoretically double and if at the final amplifiers they could blow. I had one customer that this happened to and it didn't blow all of the final amps just most of them, enough that he had trouble communicating. The higher the transmitter power the more these kinds of troubles occur. I had another customer that had a problem with his engine instruments wiping out on transmit. He had a high power and a low power transmitter so he connected his low power one to his bad vertical stab antenna and his high power one to one of my SA-006 Com antennas mounted in his fuselage and he has been smiling ever since. He now uses the low power for ground control and such and the high power for airborne communications. He also had an autopilot problem that was solved prior to the antenna fix by the autopilot manufacturer recommending a diode be installed in the autopilot, I'm not sure where but probably across the power input.

I would highly recommend testing all installed antennas for VSWR prior to sealing up any areas that will not be accessible after closing. Most Ham radio operators have VSWR meters that would do the job and would be willing to help. I would recommend testing at least three frequencies and four or five would be better to make sure there are no bad frequency spots. The copper strip type antennas tend to be pretty narrow banded and if well centered in the frequency band the high and low frequency VSWR will probably be 4 or 5 to 1. I have tested several of these copper strip antennas though that have tested very well and I don't know why. Maybe they were lossy, such as the ferrite transformer style. Also long cables tend to mask high VSWRs.

I have heard about another problem lately not pertaining to RF interference but still a possible problem. From two sources I have heard about, of apparently not being able to receive or transmit through the glass skin of the aircraft. In one of these cases the story was that a primer / surfacer of some type that was imported from Germany was used. In both cases the aircraft were Glassairs and I don't know if it is the construction materials or coatings or some other reason but it would be a good idea to check out the transmissibility of the skin. This would be easy to do using a hand held GPS receiver set on signal strength outside the aircraft and then moving it inside and checking the difference. The GPS signals are much higher in frequency so if the GPS signals get through the VHF frequencies would have no problem. In my experience in testing materials and coatings I have found that if the coatings were not conductive they did not have much effect. I have not of course tested every type of material, so test. Again, I highly recommend that ALL antenna installations be tested after installation and before sealing up if at all possible. I have recently also tested one of my antennas installed inside a large rudder which tested pretty bad. When tested outside the rudder it tested fine. It seems this vender used some kind of Zinc Chromate primer that was VERY heavily doped with the Zinc Chromate and apparently it was detuning the antenna. Not recommended! Very lossy too!

With all glass, or I should say non-conductive, aircraft an additional problem is the total lack of the shielding provided by the metal, or graphite structure. The conductive aircraft provides at least some shielding from the radiation from the monopole on a ground plane type antenna. Again that radiation can and does get into every conductor in the aircraft.

I have tested all of my antenna models on actual aircraft installations and if installed as per the installation instructions have an installed VSWR of less than 2:1 which is very good. I have also checked some installations that had a high VSWR and most of these turned out not to have been installed properly.

Aircraft noise can also be a problem. Sources can be alternators, generators, fuel pumps, magnetos, strobe systems etc. All of these devices can be the source of noise that can be transferred into the radios. This noise gets onto the main bus and thence into everything. All the modern electronics equipment are controlled and operated by digital signals which are short duration square waves which can also leak out of the equipment and into every thing. LCD displays can be very sensitive to these signals.

I have been recommending that folks with these kinds of problems do a noise testing program by testing for noise sources with and without the engine running and with and without all the various pieces of equipment running. This should turn up something. To kill some of these noises I have been recommending installing capacitors of about .25mfd to the bus and various places for the lower frequency noise and for the RF problem use capacitors of about 50 pfd. Old fashioned automobile ignition capacitors are in the ball park for the .25 caps.

I hope some of these ideas might help.

Good Luck!.

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TENNA TIP #6: WING TIP ANTENNAS FOR METAL and/or CONDUCTIVE AIRCRAFT

The highest performance internal / flush aircraft antennas available at any price.

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What? Are you crazy? Everyone knows that wing tip antennas
have never, will never and cannot ever be made to work !!!

(Semi close to actual quote by semi-famous antenna guru who
shall remain anonymous.)
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The above quote is absolutely true for antennas that are designed the traditional way; (of course the meaning of "works" is subjective, some people think an antenna "works" if they can communicate with the tower while being parked at the base) by connecting a conductor longer than a quarter wave length to the center conductor of a coaxial cable, with the outer conductor connected to a ground plane and then trimming the antenna element until you get the lowest VSWR.

Doing this in a fiber glass wing tip on the end of a conductive wing leads to several problems. The end of a conductive wing is not a "plane", as in a large flat surface, against which monopole type antennas are normally meant to work. Also to get a quarter wave antenna element in a wing tip the antenna normally will have to be bent or swept back in order to fit into the tip and this causes more capacitance between the element and the end of the wing than the antenna can use. And then we have the wing tip lights and wires which also cause more capacitance and on top of that the wires are a very low impedance for the RF energy to ground and they tend to bleed off antenna energy to ground.

With these problems to work with a fellow worker and I, from TRW in Redondo Beach where we were employed as antenna designers and developers for space craft, were hired to develop internal zero drag antennas for the "Derringer", a two place twin engine aircraft being developed by the High Shear Corp. at the time. (Early sixties). The antennas we developed were COM, VOR and Marker beacon, they worked very well and had good VSRW but were very complicated and hard to install in the wing tips. The COM in particular, it had both series and parallel capacitors with a very critical inductive element. The workers in the plant never did build one that worked even after we showed them how three times.

So they put external antennas on their airplanes. Easier. In the aftermath a friend with a Bonanza, with a rabbit ears type of VOR antenna under the tail, complained that he only had a reception range of about 35 miles. So we modified the existing wing tip antenna design to make it easier to install, certified some fiberglass wing tips and tried to sell the tips with antennas to Bonanza owners. The friend installed a set on his airplane and informed us that he could get a full flag from the SFO VOR over Gorman at 13000 feet.

I didn't witness it but I do know they worked well. Beechcraft didn't make them though so Bonanza owners weren't much interested. So my partner quit leaving me the business and I modified the antennas some more deciding they had to be stand alone items so that I had total control over all the parameters and would fit into any wing tip that is large enough. I sold T-18 builders quite a few wingtip VOR antennas over the years and added a tail top COM antenna to my product line in the early seventies. This COM works out very well but some folks don’t like the looks of the taller tail.

In the early nineties people were becoming more aware of the drag penalties of external antennas so they were coming to me for help more often. Also composite aircraft were becoming more popular so I expanded into internal dipole antennas also. At this time I have probably sold more VOR wing tip antennas to Lancair IV builders than any other type of aircraft. One builder told me he has a VOR reception range of 200 miles. It is pressurized and he flies high but still that is pretty good. RV builders tell me that they can always depend on well over a hundred miles if they are at any kind of decent altitude. I recently, by popular request, came out with a wing tip COM antenna that seems to work pretty well, though not as well as the tail top COM, with users reporting communication ranges of greater than fifty miles.

Most of the antennas I make use a device that is called a "Gamma Match" to feed the antennas and match the impedance. I use this device because I then have control over all the parameters of the antenna and allows the matching of impedance to a high level across the frequency band. I can control the over all length of the elements, can feed the antenna at the fifty-ohm point of the elements and can vary the inductance and capacitance to the point where they operate at the point of the best possible performance.

A note of caution: the same noted antenna guru as noted above recommends connecting two wing tip antennas together through a two set coupler and then dividing the signal again through another coupler to two receivers in order to attain better coverage all the way around the aircraft. Though this sounds like a logical thing to do it is very poor antenna practice. Unless you REALLY know what you are doing I would say NEVER connect two antennas together in a way that would sum the signals. Because of the distance between the wing tips as the aircraft rotates about its vertical axis the distance from the antennas to the station will change causing the signal to arrive at the antennas at different times.

There will therefore be times when the signals arrive at the antennas with zero difference in time and are then said to be in phase and the signals will add, but there will be angles where the signals will arrive at times when the signals are a half a wave different and they will then be 180 degrees out of phase and they will add negatively and there will be no net signal. The radiation pattern will then look very much like the petals of a daisy.

I once had a customer that had hooked his antennas together as mentioned above and his Localizer had a null right on the nose. It is very difficult to follow with the needle swinging back and forth and the signal dropping out. The two-element dipole antenna should have a balun installed for proper operation. By this I mean a REAL balun. NOT a wadded up ball of steel wool, NOT a couple of ferrite beads and not a ferrite transformer balun. All of these things will "WORK" of course but not at a performance level at which good antenna designs will work. A proper balun does the following jobs:

- Matches the impedance of a 50 ohm transmission line to the nominal 150 ohms of the two element dipole.

- Balances the RF currents on the antenna elements so that the radiation pattern is not squashed or deformed.

- Provides a quarter wave RF choke that prevents any energy that is reflected back down the outside of the RF cable, because of high VSWR, from radiating and adding, positively and negatively, to the radiated energy and also prevents the RF from traveling to the area behind the instrument panel and causing all kinds of gremlins.

I have had many people with the above kinds of gremlins in their airplanes install my antenna designs in place of the copper strip type with the result that the gremlins all left in a hurry. I have also had people that installed proper baluns on their copper strip antennas with very good results. I will send a balun drawing to anyone that sends a SASE to me. Its isn't a very pretty drawing but it does get the idea across.

My recommendations for antennas on RV aircraft are as follows:

Com antennas; The top of the tail is the absolute best location for a com antenna because it is high above the rest of the aircraft and no part of the aircraft can block the signal, unless close and then it won’t matter anyway. All other locations will provide blockage in one direction or another. Even the external ones. Recently builders have been installing wing tip Com antennas that I make and they seem to be working well. I am certain they are not the absolute optimum but people tell me that they can always communicate. One builder reports that tuned to an airport ATIS at 50 miles he could always receive while flying circles.

Nav antennas; The wing tip Nav antennas appear to be working out extremely well with reports of reception well over 100 miles at any sort of decent altitude.

Transponder; The best you can do is the blade type of antennas. The are very well tuned normally and strong so they can’t be broken easily and the have low drag. Install them to the rear of the landing gear, about two feet or so, so the landing gear interference is minimized.

GPS antennas: All sets come with an antenna and they must be mounted on the top of the aircraft so it can see the sky. They do not need a ground plane so they can be mounted on insulation if desired. The top of rollover structure or the top of the panel or the rear deck all work well.

Marker Beacon antenna: A simple and cheap antenna can be fabbed by installing a 40" long conductor in a wing tip under the wingtip VOR antenna about 3" from the end of the metal of the wing. Connect a center conductor of a coax to one end of it, ground the braid if you like, not necessary, and you are home free.

Below are terms frequently used in antenna parlance with short definitions.

- Active Elements? The part of the antenna that actually does the radiating or the receiving of the RF energy.

- Aperture? The capture area of the antenna. On a dipole or monopole it is the overall dimension of the active elements, on dish antennas it is the diameter of the dish. On an aircraft the largest conductive dimension.

- Feed point? Generally the point at which the coaxial cable attaches to the antenna but could be where the feed device attaches to the active elements

- VSWR? Voltage Standing Wave Ratio. The measurement of the ratio of incident to reflected RF energy. An indication of the quality of energy transference. The lower the number the better. 1:1 is perfect. 2:1 is good ,3:1 is OK, 4:1 and up is poor to terrible.

- Radiation Pattern? A pattern showing the relative signal level around an antenna. Signal strength can be severely reduced in particular directions by other antennas, vertical stabilizers, landing gears etc.

- Balun? A device that converts a balanced transmission line (such as TV lead in) to a coaxial line which is an unbalanced line. Provides balanced currents on dipole antennas while matching the 50 ohm line to the nominally 150 ohm antenna.

- Polarization? The plane in which RF energy is radiated. Normally either vertical, such as COM, or horizontal, such as VOR, or any angle in between, such as bent COM antennas. There is also circular polarization, which is used in most spacecraft antennas.

I will answer any antenna questions you might have either by snail mail, telephone or by E mail at bobsantennas@earthlink.net

TENNA TIP #7

ANTENNAS FOR STEEL TUBE AIRCRAFT
(W/ Wood Wings) or (Glass?) or?
by Bob Archer of Sportcraft Antennas

The art of installing antennas internally that really work properly into aircraft with steel tube fuselages and wood wings has left many people confused and perplexed and all the worlds flooby dust doesn't help so I have decided to try to give some tips and information on the subject. Some people have tried to install monopole antennas internally with a ground plane installed for the antenna to work against and this is just totally bad. One friend of mine informed me he had installed his COM antenna inside the aluminum box of his baggage compartment and it worked just fine. I beg to differ, but if he is happy with it who am I to knock it. Com antennas are vertically polarized and so need to be installed vertically. My number one preferred location for a COM antenna on any type aircraft is the top of the vertical stabilizer where it has a very nice field of view all the way around but that is not very practical on this type of aircraft. Lots of welding and approvals needed. At one time I was going to try a special feed device that I have developed to turn the entire vertical tail into an antenna but my friend with a spare fuselage moved away before I got a chance to attempt it. So there is no good way to install an internal COM antenna in a Bellanca that will work the way I believe an antenna should work. I also believe that it is better to use one really good antenna rather than two mediocre (or poor) ones. I have on my airplane a really good Transco broad band low drag antenna mounted to the belly pan next to the access panel and hooked up to both radios through a coaxial switch. It works very well and the VSWR checks out real well though I would prefer a larger ground plane. On my last trip to Phoenix I tuned in the Williams tower after crossing the river and could hear the aircraft in the pattern but not the tower. I didn't check the distance but I think it was well over 100 miles. I have had some problems in some locations talking to control towers while on the ground though. The landing gear legs will interfere with the gear down and I think the ground itself is lossy in some places and soaks up the RF energy. The last possible location for a COM antenna to work well is the top of the fuselage but there are problems. The steel tube structure can be used as a ground plane but to work properly the antenna ground must be tied electrically into the tubing. Remember, a ground plane at these frequencies should be about 48 inches in diameter at least to work properly. Larger is better. An antenna mounted to a smaller plate and the plate then attached to the tubing will be OK but the plate must be electrically attached to the tubing and I do not mean with a ground wire. Ideally the ground currents should go into the ground plane in a radial manner in several places but do the best you can. If the antenna ground is not done properly the VSWR of the antenna can be very high.

A word or two or several about VSWR. VSWR stands for Voltage Sanding Wave Ratio, Not Variable Standing Wave Ratio as was reported in a recent KITPLANES article. It is the ratio of the incident RF waves (those being transmitted) to the reflected RF waves (those being reflected by an antenna that is not matched properly to the impedance of the transmitter and the transmission line). Most Aerospace companies require a VSWR of less than 2:1 for transmit and 3:1 for receive. I require all my antennas to be less than 2:1. A VSWR of 2:1 reflects about 10% of the energy and 3:1 reflects about 25% and above that is way to much.

With wood or Glass wings you can install a VOR antenna in each wing out toward the tips .In my airplane I used two copper strips and a type two balun all of which were installed through the outermost inspection hole. I snaked the copper elements through the ribs and drilled holes through the plywood skins to attach the strips and balun together. Biplanes are particularly poor candidate for antennas in the wings with all the drag and anti drag wires and the compression struts and other stuff. But if the biplane wings have metal leading edges and wood or glass tip bows they could have VOR antennas installed in the tips using the metal leading edges as ground planes.

The following are my recommendations for antenna locations on tube and rag type aircraft with wood wings for both optimum radio performance and minimum drag. Also best visual. I hate the “Stickle Back Trout” look.

1. Com antenna. One antenna on the bottom of the cowl next to the access panel if you have one. Use a coaxial switch to connect two radios to one antenna. I would rather use one really good antenna for two radios than two lousy ones. On the ground at some airports you may have some problems. I make a special switch that allows receiving on two radios and transmitting straight through to the single antenna when transmitting.

2. Vor antennas. One antenna in each wing for each receiver out toward the tip. Install through the outer inspection hole using flat head screws through the top surface of wing to secure balun. I have drawings of baluns for anyone that wants them or I can provide the baluns. One antenna into each VOR receiver will increase your VOR range about 25% over one antenna with a splitter.

3. Marker Beacon antenna. Standard boat type antenna may be installed in aft fuselage looking between the steel tubes. Or a 40 inch long conductor, metal tape or wire, could be installed inside on the bottom fabric alongside the bottom stringer with the center conductor of the coaxial cable connected to the conductor and the braid can be grounded to the aft edge of the bottom aluminum sheet behind the access panel but would not be required.

4. GPS. Inside the top fabric. I have mine installed between the fabric and the headliner over the cabin. My tests show no significant signal loss due to the aluminized fabric. Do not need a ground plane. On newer sets the antennas all have built in amplifiers an dseem to just plain WORK!

5. Transponder / DME. A standard external monopole may be installed on the bottom metal near the bottom access or install one of my SA-005 dipole transponder antennas as I did inside the wing about half way out to the tip. It needs about six inches of wing depth for the installation. I installed mine through an inspection hole by trimming off enough of the excess fiber glass to allow it to fit through the hole. I then bonded it to a rib with the six inch dimension vertical and connector pointed toward the cabin. I used RG58/CU cable but if I had it to do over I would use a little better cable like RG55/U or RG 142/U cables perhaps.

6. Glide slope. Just couple the glide slope signal off the VOR antenna with a coupler box. Unless you are using a towel bar antenna or one of the small blade types. They don’t seem to support the glide slope frequencies.

7. Loran. Does anyone still use Loran? I do! Very sensitive to aircraft electrical noise. Need filters on every thing that could be noisy. Very low frequency with vertical polarization. A six foot ADF whip antenna would be great. Or a long wire antenna. Do the best you can. Get the maximum vertical dimension possible. I have a wire antenna going from an insulator at the base of the windshield to a short mast just aft of the upper edge of the windshield. I originally had a long wire antenna going all the way to the top of the vertical tail but it broke due to vibration. I wrapped the end of the broken wire around the mast and it worked just as well. So I left it that way. I did neaten it up a bit though.

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