BEST Robotics Incorporated
Field Transmitter Construction
Revision 3.0

Revision History:
1.0 Original release.
2.0 Added current limit circuit.
3.0 Removed the 3.5mm jack from cable, replaced with 6 pin DIN plug. Added power cord extensions for the "RAD to the Core" field.

The "tether system" which many hubs are using in 1999 is a method of allowing more than 30 teams to compete in one location without their RC transmitters interfering with each other. We do this by disabling the transmitters of all the teams and using a wire (or "tether) to connect the signals from their controller (the box with the joysticks) to transmitters which are built in to the field ("field transmitters"). In this way all teams use the same 4 transmitters and no other transmitters are used.

These instructions explain how to build these field transmitters.

Figure 1 – Plugged in and ready to roll!

Figure 1 shows the tether system in action. The team has their controller plugged into the white PVC pipe containing the field transmitter, which is mounted into the boundary of the field and powered using a cable contained within the field boundary.

Our plan is to have five RC sets for the field, each set consisting of a transmitter and two matching receivers. This way we can be removing the receiver from the machine that just came off the field and be putting it on the machine in the waiting area while a third machine is playing on the field using the second receiver. This requires four sets for a four-player game; the fifth set gives us a backup system in case anything happens to one of the four sets needed for the game field. So, before you begin construction of the field RC system you need to have 5 transmitters and 5 pairs of receivers (10 receivers total) matching the transmitters' frequencies.

Parts List

Quantity	Description
5	Futaba Skysport 4 Transmitters
10	RC receivers, 2 matching each transmitter
1	10' length of 4" PVC thinwall sewer pipe
5	End caps to fit 4" PVC pipe
1	Power Supply, 9V to 11V, 1.5A
5	Coaxial power jacks 2.1mm ID / 5.5mm OD
5	Coaxial power plugs 2.1mm ID / 5.5mm OD
10'	Single conductor wire, 20ga to 26ga
125'	Two conductor wire, 20ga to 24ga
5	2 conductor plus shield wire, 24 ga, 10' lengths Mouser Part # 566-9501-100 for 100' spool or equivalent
5	6 pin DIN plugs, Mouser part # 174-2611
???	Some foam rubber
5	Small cable ties
5 sets	3" mailbox numbers or large adhesive letters
20	½" screws

The plugs, jacks, and wire are available at Radio Shack or from Mouser Electronics, on the web at "www.mouser.com".

These instructions are written around the Futaba Skysport 4 system, transmitter model number T4VF. Other models can be adapted similarly. (I understand the Conquest transmitter is very similar except the power meter is more difficult to remove, requiring some broken plastic.)

We do not use the transmitter as-is for the field. Instead, the circuitry is removed from the original plastic case and is built into the field. Each is hardwired "on" and with the buddy switch activated. The circuitry is repackaged in a 4" PVC pipe, which in turn fits into a PVC "T" in the field boundary. The completed field transmitter has only two connections – a power connection on the

bottom, inside the field boundary, and a buddy cable connection on the top, accessible to the teams. The antenna is contained within the PVC pipe. This makes the field transmitters much more robust, being securely attached to the field and having only one plug on a cable with which the teams must deal. If they forget about the cable in their excitement and yank on it, they will just unplug their controller. This will cause them to lose control of their robot (until they re-connect) but will not damage the field transmitter.

Field Transmitter Construction

The first step in building a field transmitter is to "gut" the factory transmitter. We will be removing all the electronics from the original case. Here are step-by-step instructions.

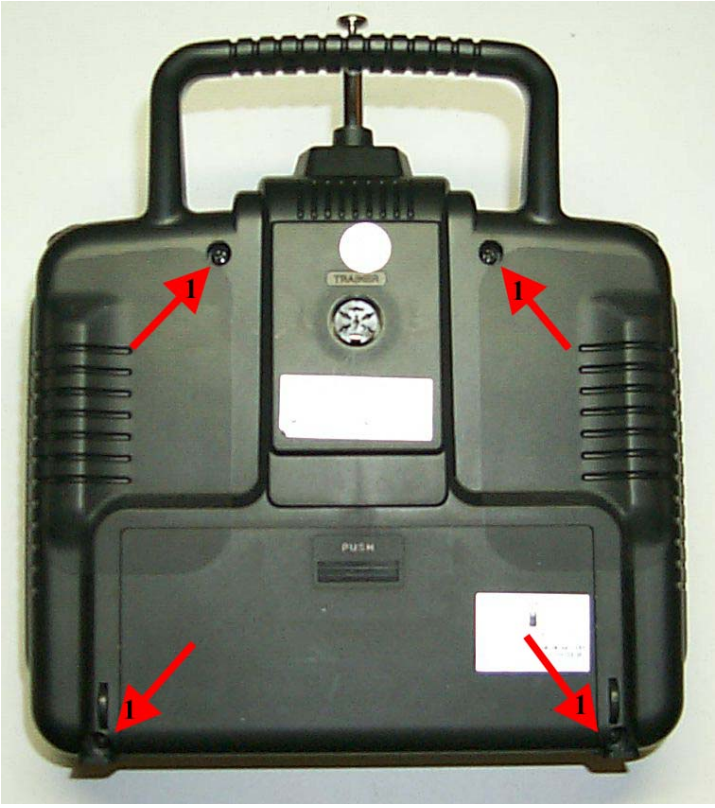

Figure 2 – The screws holding the case together

Remove the back of the transmitter. You do not need to open the battery compartment or remove the batteries. Remove the four screws indicated by the red arrows (1) in figure 2 above and the back will come off. Note that the battery, inside the battery compartment, is connected to the main circuit board by two wires. Unplug the battery wires from the main circuit board and set the case back and batteries aside.

The small circuit card holding the buddy connector (a 6 pin DIN) is now loose and you can lift it out.

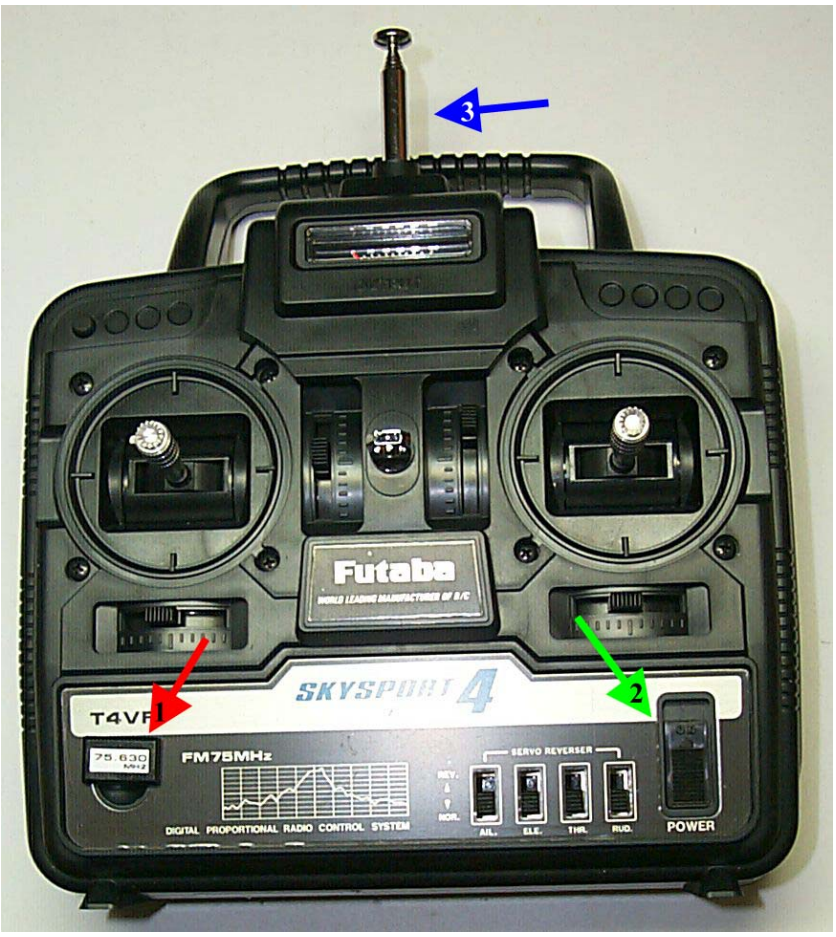

Figure 3 – Crystal, power switch, and antenna

Referring to figure 3, unplug the crystal (red arrow, 1) from the front of the transmitter. Turn the transmitter power switch (green arrow, 2) on. Pry off the plastic cover from the power switch using a small flat-bladed screwdriver. Unscrew the antenna (blue arrow, 3) and remove it by pulling it straight out of the case.

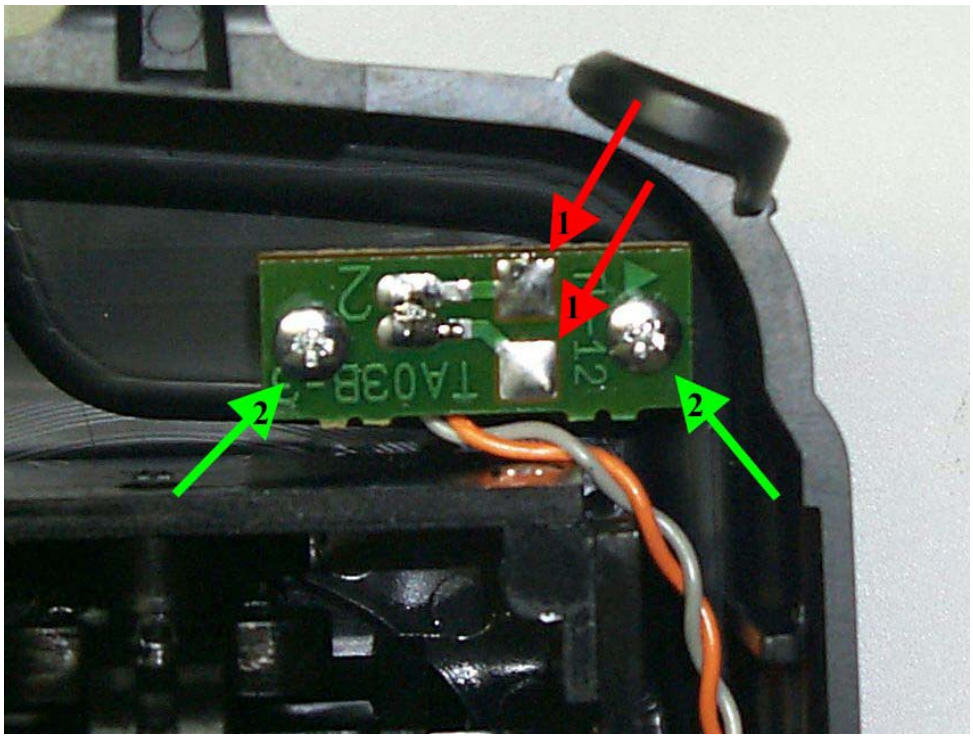

Figure 4 – Close-up of the trainer switch

Flip the transmitter over so you are looking at the back again. You will find the small circuit card holding the trainer switch in the upper right corner (see figure 4). Solder a jumper wire across the two square lands indicated by the red arrows (1). This will hardwire the transmitter into the trainer position, taking its control signals from the buddy connector instead of its joysticks. After soldering the jumper, remove the trainer switch PC card by removing the two screws (green arrows, 2).

Figure 5 – The screws holding the joysticks in place

Take out the two joysticks by removing the 8 screws indicated by red arrows in figure 5.

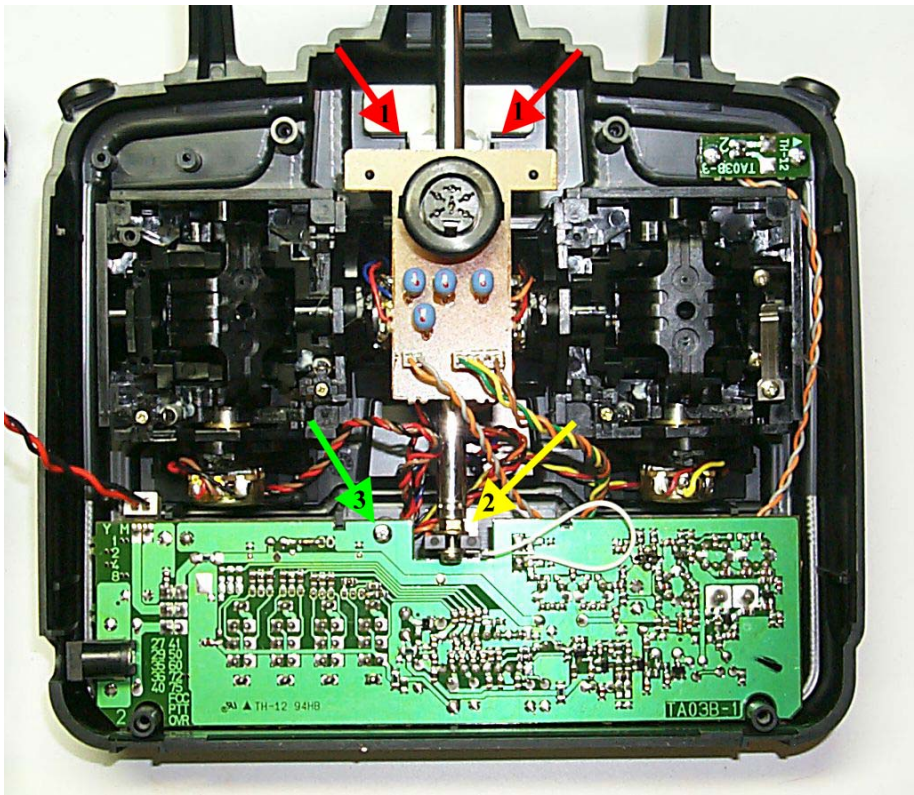

Figure 6 – Meter, antenna, and PC board mounting

Take out the power meter by prying apart the locking tabs (red arrows, 1) while pushing on the face of the meter. In figure 6 the locking tabs are partially hidden by the buddy socket board.

Unscrew the antenna mounting hardware (yellow arrow, 2) from the chassis. The chassis mount is a slot, so you only have to loosen the nut and the screw will slide out of the slot. Cut a 2' length of insulated wire. The gauge is not important, 20 to 26 gauge works fine. Strip one end and fasten it to the antenna wire using the antenna mounting nut and bolt.

Carefully remove the main PC board after removing one screw (green arrow, 3).

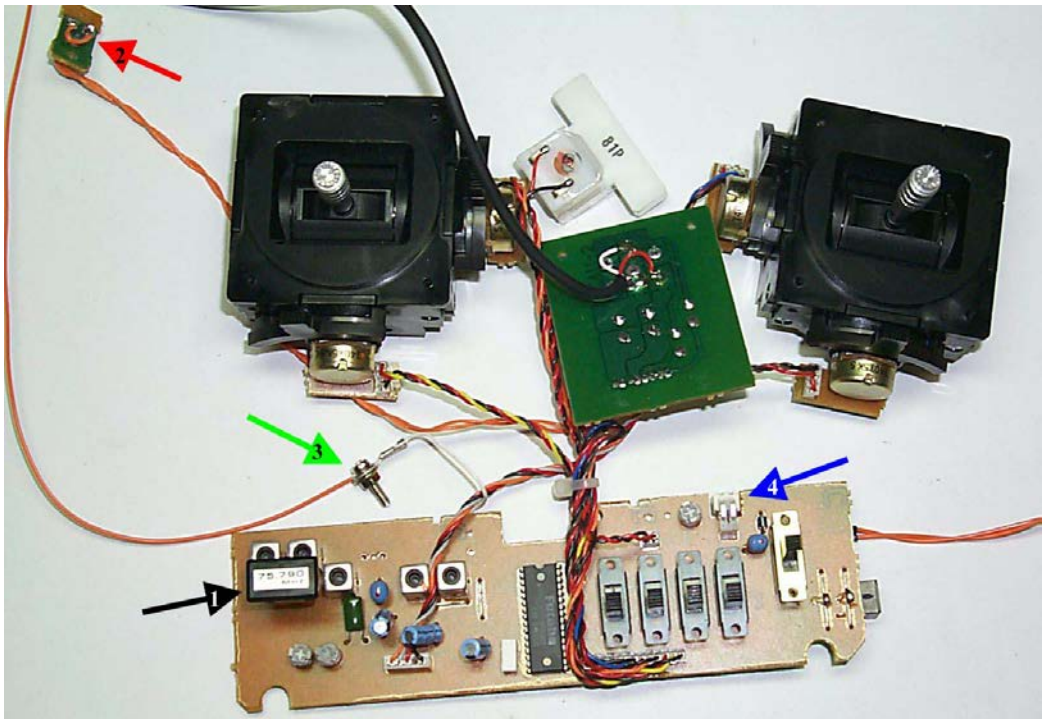

Figure 7 – A transmitter spills its guts!

Now you should have all the electronics out of the case as shown in Figure 7 above. *Do not turn the adjusting screws in the silver metal cans or on the plastic adjustable resistors.* If you do, the transmitter will no longer work properly.

Plug the crystal back into its socket (black arrow, 1).

If you put all the loose hardware into a ziplock baggie and keep it with the case, you can put the transmitter back into its case in the future should you so desire.

There are a few things to note in figure 7. The red arrow (2) points to the trainer switch board; you can see the orange jumper wire across the switch terminals. The green arrow (3) points to the antenna connection to the orange extension wire using the antenna mounting hardware. The blue arrow (4) points to the power connection from which you unplugged the battery and to which you will connect the external power supply.

The wires from the joysticks and smaller boards appear to be connected to the main board through white plastic plugs. These are not plugs, but merely wire holders of some kind; the wires are actually soldered to the main board. Thus, we cannot simply unplug the joysticks. We'll just leave them connected.

Next on the agenda is to connect a cable with a 6-conductor DIN plug to the board holding the DIN jack. Looking at the back of the board and the back of the socket, the DIN pins are numbered like this and connect as shown:

```
DIN socket                                        DIN plug

     3_____________________________________
                                            |   3
 4       2                                  2       4
                                                6
     6    ___________________________________1       5
          |                                     G
 5   G    1                                     |
     |___________shield/braid_________________|
```

Figure 8 – Close-up of the DIN board

Solder the wires as shown in figure 8. Connect G (ground) to G, 1 to 1, and 3 of the socket to 2 of the plug. Your cable color and wire colors may be different than those in the photo. The location of the DIN terminals corresponds to the physical location of the numbers in the "schematic". Make sure all of the small wires of the shield are gathered up and soldered to the ground terminal so they will not accidentally short to any other traces on the board. If your cable has a foil shield, trim it as well.

See appendix 1 for information about a current limiting circuit you can add in series with the power wire. Adding this is highly recommended; it will prevent shorted DIN cables from damaging components on the Futaba transmitter boards.

The power cable is next. This is 2 conductors and 24" long, to extend out the bottom of the PVC pipe into which we will place the transmitter. The bottom end of this cable will have a 2.1mm ID

/ 5.5mm OD coaxial power jack which mates with the plugs that are on the power wiring in the field (more about this later). The top end of this cable attaches to the transmitter board.

Pay close attention to the polarity of the wires in this cable. If you get the wires switched and apply the wrong polarity voltage to the transmitter board it could be severely damaged (I never tried it, but I'll bet the board will be ruined).

At the bottom of the cable, connect the positive wire to the **outside** terminal of the jack and connect the negative wire to the **inside** terminal (the pin in the center of the jack).

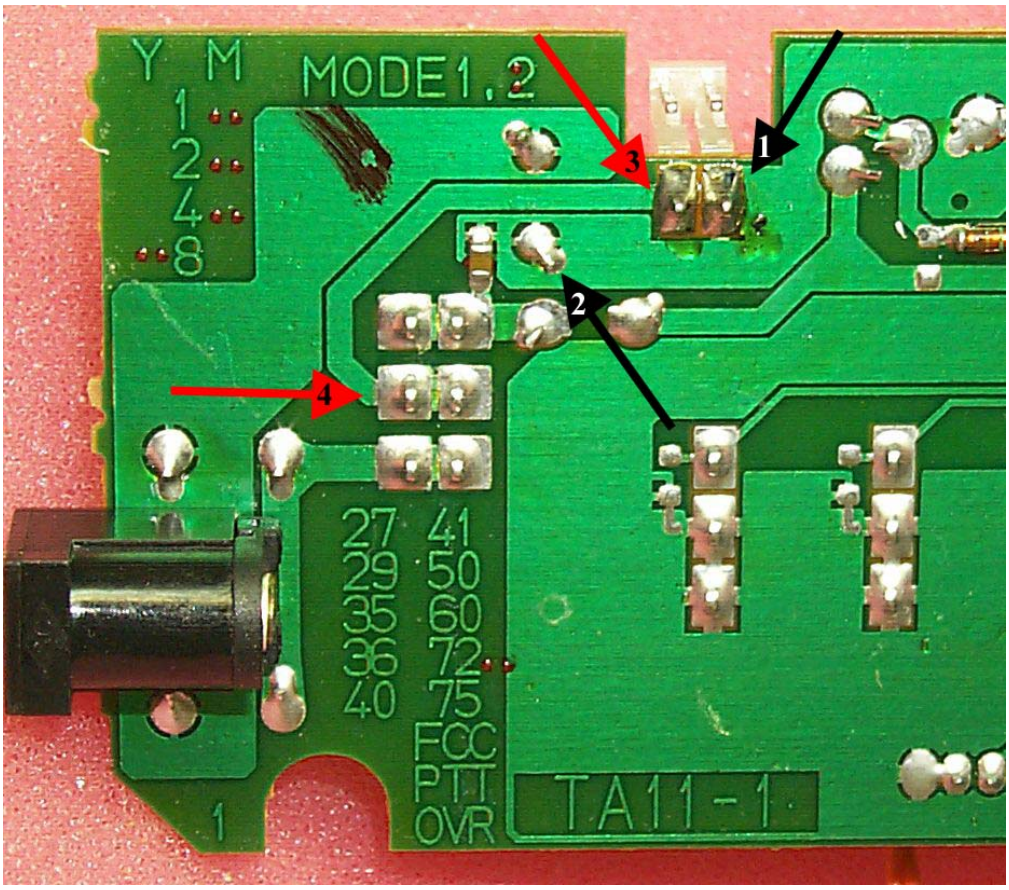

Figure 9 – Power connections on the main PC board

There are three ways to connect the power cable to the main transmitter PC board. What we did in NT BEST is to use the connector to which the batteries were connected. This white connector is visible in figure 9 through the square cutout at the top of the main PC board. The positive terminal is the pin on the left, near red arrow #3; the negative terminal is the pin on the right, near black arrow #1. Either cut the mating connectors from the battery packs (be sure to leave enough wire to solder and insulate well after soldering), or get some similar connectors if you wish to preserve the battery packs. I found some mating connectors at Radio Shack. Radio Shack does not carry this connector in their parts section, but the folks at our store let me look through their box of NiCd batteries to be recycled and I found some suitable connectors there. (*When cutting connectors from battery packs, do not cut both wires at the same time.* This will short the battery and could be dangerous. Instead, cut each wire singly.)

A second way to connect the power to the board is to solder the top of the 24” power cable directly to the circuit board (as was done with the 3.5mm jack on the DIN board). This has the advantage that you know it will not be pulled loose.

A good place to connect the positive power wire is to the center switch terminal (red arrow #4) because the connection by the white connector (red arrow #3) is very close to the negative terminal (black arrow #1). Connect the negative power wire at the land marked with black arrow #2.

The third way (not recommended) is to use a plug that mates with the charging jack on the transmitter PC board. If you do this you will have to put a jumper somewhere (I haven’t figured out where) on the power switch because the charging jack is disconnected when the power is turned on.

Now it is time to build the “case” for the field transmitters. Get a 10’ piece of 4” thinwall PVC sewer pipe. It will be flared at one end, we don’t use the flared end. Cut 5 pipes of length 23” from this pipe; discard the flared leftover end. Get 5 end caps to fit these pipes.

Figure 10 – PVC pipe with cross brace

Measure down 10” from the “top” of each section of 4” pipe. Put a brace across the inside of the pipe here. As you can see from figure 10, I used some 1” PVC pipe, cut to 4” long. It is held in place by a screw at each end. The screws just go into the hollow interior of the 1” pipe, but they keep it from slipping down. You could also use a piece of wood or plastic for this brace; anything non-conductive will work fine.

Hold the transmitter “rat’s nest” by the large PC board, with the meter, joysticks, and power cable hanging down and the 3.5mm stereo jack cable and the antenna going up, and lower it into the 4” pipe until the joysticks are resting on the brace. Let the large PC board rest on the joysticks. The power cord should come out the bottom of the 4” pipe.

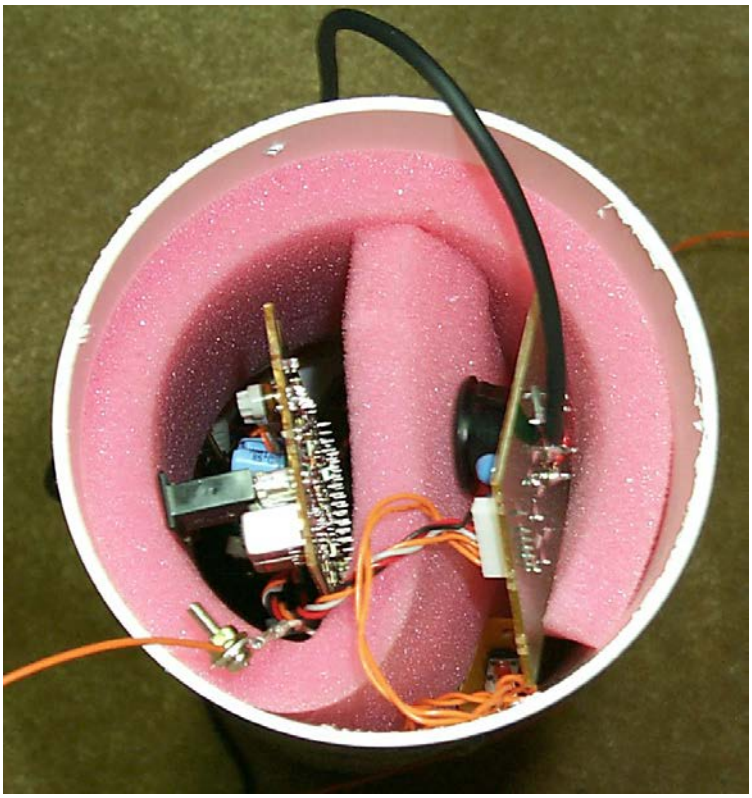

Figure 11 – a packed tube

Pack around the PC board with some foam rubber as shown in figure 11 (you'll have to scrounge this foam…). Make sure the antenna wire (especially the bolt and nut) is insulated from other metal. Run the antenna wire down the outside of the foam rubber, but inside the 4" pipe, so it also comes out the bottom (it will just reach the bottom).

Figure 12 – The finished field transmitter!

Drill a ½" hole in the end cap for the 3.5mm stereo jack to pass through and two 1/8" holes for a cable tie strain relief. Sand or countersink slightly the edges of the ½" hole so they will not chaff through the cable.

Run the cable with the 3.5mm stereo jack through the large hole. Fasten the cable tie as shown above around the cable both outside and inside the end cap. Leave only a few inches of slack inside the pipe; you should have about 4' of cable outside the pipe.

Put the end cap on the 4" pipe and fasten it with 2 screws. Use short screws so they don't get into the circuit boards.

Number each completed field transmitter using large (3") mailbox numbers. Be sure to record which frequency transmitter is inside each tube as it is not possible to see the label on the crystal now!

Field Power Supply Construction

You will need to have some kind of external power supply for the field transmitters. The transmitter batteries (which we removed) will not last through the day. You can only count on about 60 minutes of battery operation before recharging them (which takes 15 hours) or swapping them (which is difficult to do).

The field power supply must be a regulated power supply between 9V and 11V capable of supplying 1.5 Amps. A 12V supply, while easier to find, is too high voltage and will damage the field transmitters. Mouser Electronics carries a suitable supply, 9V at 1.6 Amps, part # 552-PSC-15A-090S, about $13, except that the plug is the wrong polarity. Be sure to change it!

Put a 2.1mm ID / 5.5mm OD power plug on the output. Connect the center of the plug (the hole in the end) to the negative lead and the outer part of the plug to the positive lead.

The power is distributed to the field transmitters by a wiring harness. Make a 2 conductor cable 75' long, with 2.1mm ID / 5.5mm OD power plugs to mate with the jacks in your field transmitters at 0', 25', 50', and 75'. In the middle (37.5') put a 2.1mm ID / 5.5mm OD power jack that mates with the plug on your power supply. The wire that connects to the inner terminal of the four plugs must connect to the inner terminal of the jack. **Polarity is critical.** Make sure you can trace the plus from the power supply all the way to the plus connector on the transmitter circuit board at each of the taps of the wiring harness. Double-check it before turning it on the first time. Then turn on the power supply and use a meter to double-check the polarity on the 4 plugs for the field transmitters before plugging any in.

The field for "RAD to the Core" has 2 teams at each end of a 50' long field. Thus, you will need two "Y" cables to run two field transmitters each from the plugs at the ends of the above cable. Each of these cables should be 20' long with 2.1mm ID / 5.5mm OD power plugs at each end and a 2.1mm ID / 5.5mm OD power jack in the middle.

With proper field design (hint to game designers…) the power wiring harness can be run through the PVC pipes defining the field boundary. If the field has a PVC "T" at each driver's station, we can arrange for the connectors of the wiring harness to line up with these "T" joints, plug the field transmitters in, and put the field transmitter tube into the "T". Voila! No exposed wiring and the field transmitters are securely attached to the field so they will not be pulled over (you might want to put a short screw through the "T" to hold in the transmitter tube).

Field Receivers

Build 2 field receivers for each field transmitter. Put the receivers into the black plastic boxes just like the team receivers, but instead of labeling them with the team number or RC frequency, use a large mailbox number matching that on the corresponding field transmitter.

Appendix 1 – Current limit circuit for power connection to cable with 3.5 mm jack

The cable with the DIN connector takes a lot of abuse. Even though the cable into the DIN connector has a strain relief, sooner or later someone will pull or flex it enough to cause a short between the power wire and the metal case of the connector. When this happens, the voltage regulator on the Futaba transmitter board of the field transmitter (which is supplying power to the team's controller) is overloaded and will be damaged.

This small circuit will limit the current to a safe value, protecting the Futaba board's regulator, and at the same time turn on a light indicating that the cable is bad. You can then repair the cable and continue on.

The circuit is simple to build and only costs about $1.00 per field transmitter. I highly recommend that you find someone to build and install some for you. They are easy to retrofit, connecting only to the DIN board and the cable with the 3.5 mm jack.

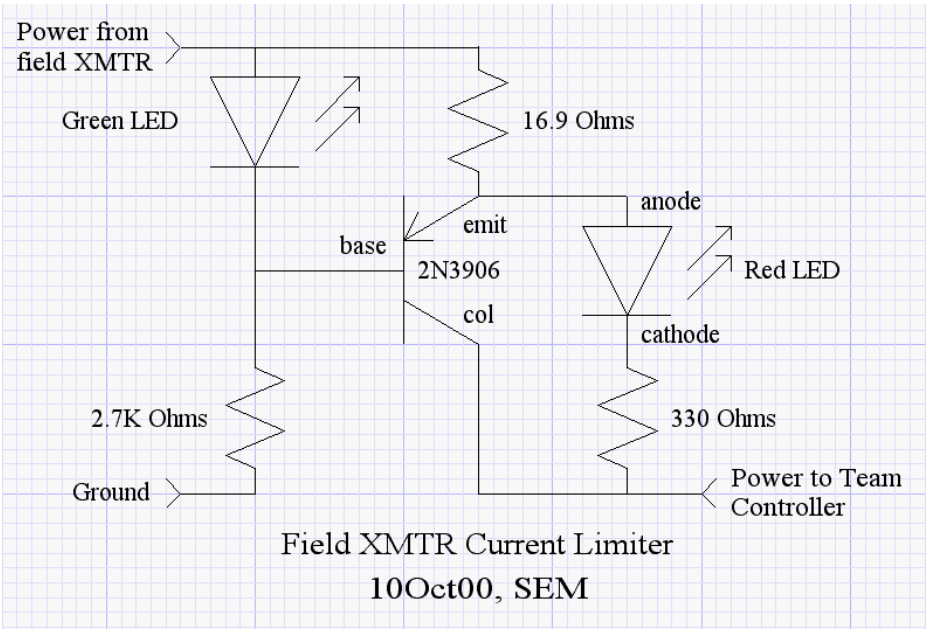

Figure Appendix1-1 Current Limiting Circuit

The schematic for the current limiting circuit is shown above. Here is a parts list for building and installing 5 circuits:

Quantity	Component	Mouser Part #	Radio Shack Equivalent
5	Green LED	351-5500	276-304 (contains 2)
5	Red LED	351-5100	276-309
5	2N3906	625-2N3906	276-2023
5	16.9 Ohm R	271-16.9	271-1102 (15 Ohm, contains 5)
5	330 Ohm R	271-330	271-1113 (contains 5)
5	2.2K R	271-2.7K	271-1121 (2.2K, contains 5)
1	Circuit board		276-168
5	4-40 x ¾ screw		
5	4-40 nut		
5	5/8” standoff		
15	12” wires		

The first six components will cost about $1/circuit from Mouser or about $3/circuit from Radio Shack. Exact parts are not critical; the Radio Shack components are their nearest equivalents to the Mouser parts. The transistor can be any general purpose PNP and the LEDs can be any red and green LEDs (although, the brighter the red LED the better).

Because of the simplicity of the circuit, it is easily wired “point to point” on a small circuit board. The board is not critical and can be a small piece of prototyping board left over from another project. If you don’t have any leftover board, I recommend the Radio Shack board, the holes are grouped together in threes with copper traces, making it easy to interconnect the components (see figure 4 of this appendix). Here’s a board I built:

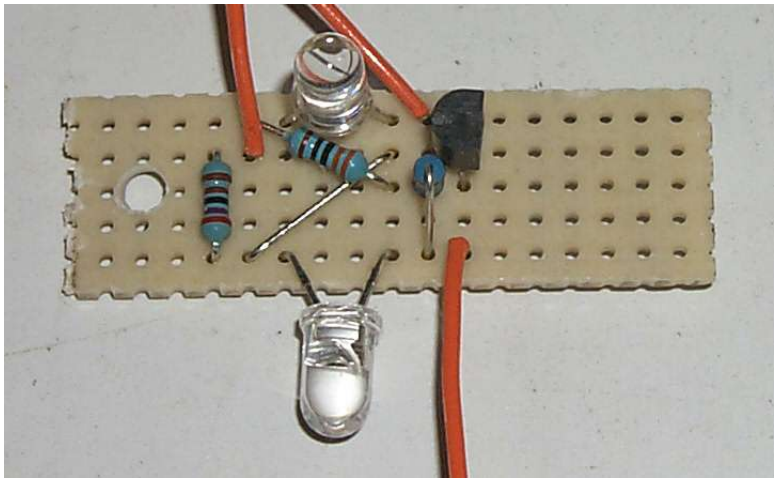

Figure Appendix1-2 Completed Circuit Board

The cathode of the LEDs is the lead nearest the flat molded in the plastic. The green LED (toward the bottom of the photo) is used only as a voltage reference and does not really light up. Bend it to the side. Make sure the lip on the red LED and everything else on the board is less than 5/8” from the board surface. Then, when you mount the board you can have the red LED show through a hole in the field tower to indicate shorts.

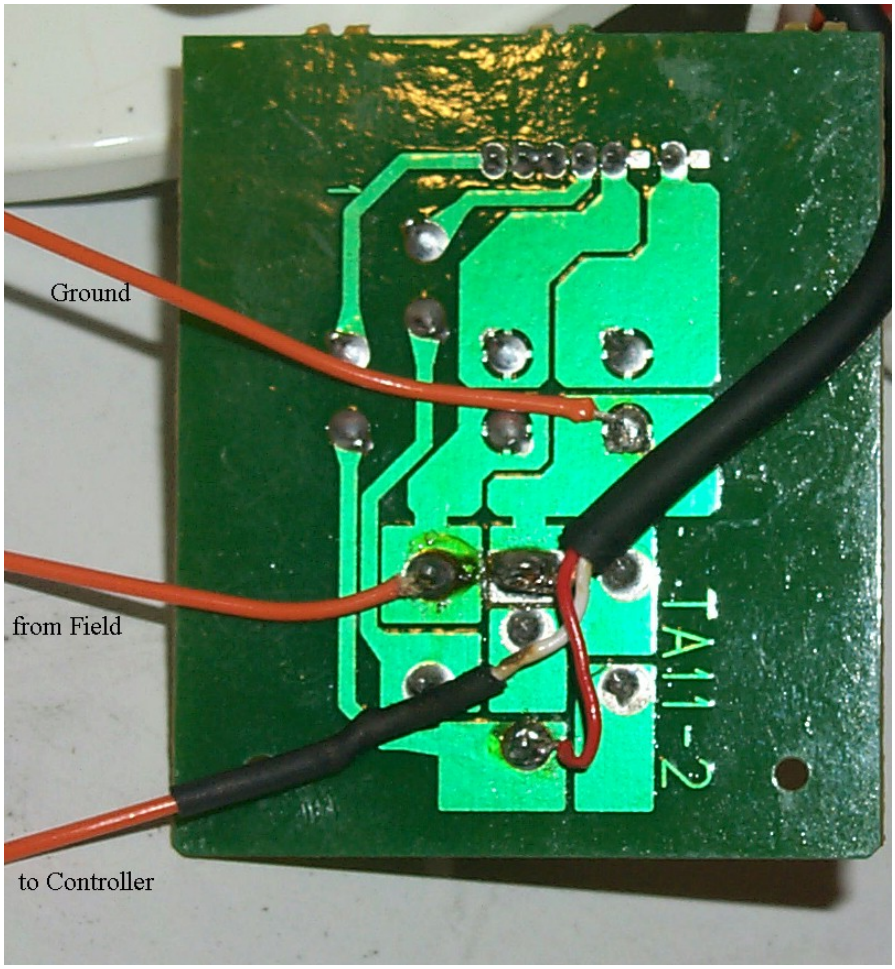

Figure Appendix1-3 Connections into the field XMTR

To install the current limiting circuit in a field XMTR, unsolder the white wire from the DIN board and solder the three wires from the completed circuit into the field XMTR as shown above. The ground wire from the current limiting circuit is the top wire and connects to the same place as the shield of the black cable; I used another solder point on the same trace to avoid unhooking the shield joint. The power from the field XMTR to the current limiting circuit is the middle wire and connects to where the white wire formerly connected. Finally, power to the team controller from the current limiting circuit is the bottom wire and connects to the white wire in the black cable. Put tape or heat shrink tubing around the connection to the white wire so it will not short to any of the other connections.

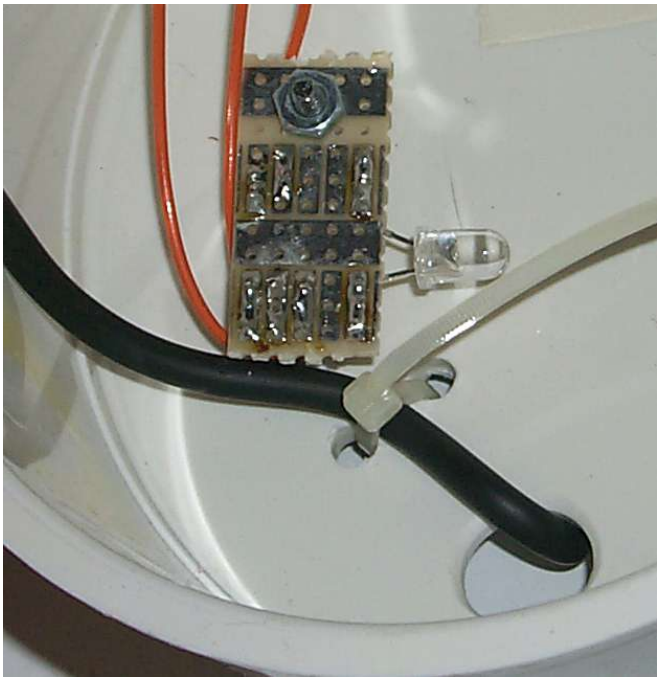

Figure Appendix1-4 The Current Limiter Installed

Drill a 1/8” hole for the 4-40 screw and an appropriately sized hole for your red LED in your transmitter tower at whatever spacing fits your board, then mount the board with the red LED showing through the hole. An alternative which would probably also work is to hot-glue the board into your field XMTR case (just hope nobody presses on the red LED…).

Now, when a team plugs in a shorted cable, instead of smoke billowing out of the field XMTR, the red light will signal you to change the cable.