CHAPTER 1 - INTRODUCTION

Thank you for purchasing the Electric Field Proximity Sensor. The EF Sensor is a micro-electronic based device that can detect the presence of both moving and stationary objects through solid materials. Its ability to operate through any non-conductive material (upholstery, carpets, sheet rock, wood) permits complete invisibility. The sensor functions by detecting minute changes in an ultra-low-power electric field generated between two remotely locatable antenna electrodes. Its range is adjustable from inches to over 12 feet and can be used to cover an entire room of concrete slab floor construction or any full room using techniques described within the operating instructions. Based on research done at MIT, the device utilizes advanced four quadrant analog multipliers to achieve virtually flawless false alarm rejection. It has application in home automation, security, manufacturing process control and safety.

In the case of home automation, there is the need to detect the presence of a person in a room to control lighting. The challenge has been that if the person was seated quietly in a chair or lying in bed, the lights would turn on or off at inappropriate times because the detector required movement. The EF Sensor solves that problem. For security, the EF Sensor's complete invisibility improves aesthetics and reduces alarm system detectability.

The EF Sensor offers significant advantages over competing technologies. Mechanical detectors (spring, membrane, etc.) often fail in applications where the spring is left compressed for an extended period--it eventually stops springing back when the pressure is removed. Photoelectric detectors, although able to sense stationary objects, are visible and must be carefully positioned. Photoelectric detectors can also be unreliable in applications subject to changes in lighting and object reflectivity. PIR (infrared) sensing is less position-sensitive than photoelectric, but requires a *moving, heated* body to respond, and the detector is still visible. PIR is also particularly susceptible to false alarms often requiring masking of sensed areas around windows and heating vents. Doppler Radar can solve the false alarm and sensor visibility problems, but still requires a moving object, and prolonged exposure to microwaves can present a health concern. Capacitive detectors have proven useful only in short range detection applications. The EF Sensor addresses all of these issues.

Specifications and Features:

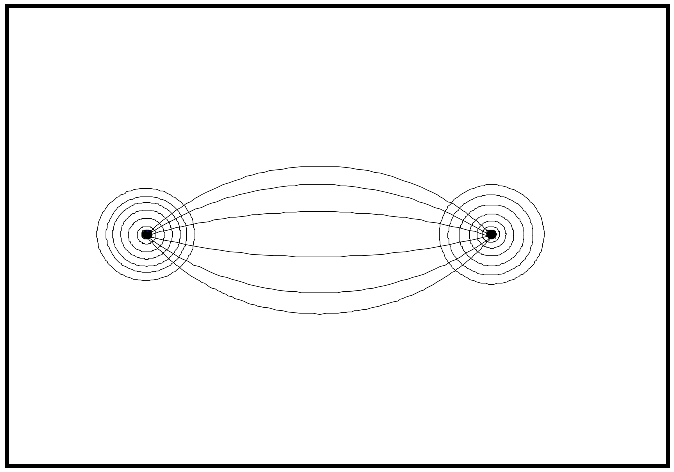
- Range adjustable from inches to over 12 feet.
- High signal-to-noise ratio (72dB).
- Single, low-profile, printed circuit board (5.5" X 3.35" X 0.7").
- Completely safe due to an RF power output of less than 1 milliwatt.
- Relay switched output (SPST 1.0 A @ 250VDC/125VAC)
- Power Requirements: 50 mA @ +12 VDC and 27 mA @ -12VDC

IMPORTANT: *Read instructions before using*

If you are looking for a quick-start procedure, begin with Chapter 3, and complete the Initial Test. You will probably find, however, that to apply the sensor to an application, it will be necessary to read the complete operating instructions. Please pay particularly close attention to understanding the difference between the shunt and transmit modes of operation and how they are achieved. Exercise caution *before* connecting the power supply to ensure that the proper voltage and polarity are applied. If you are not using a PS-1 or PS-2 power supply, the sensor requires a regulated linear supply with both + and – 12VDC for a total voltage span of 24 volts. The common terminal must be connected to the grounding prong on the power supply plug.

CHAPTER 2 - PRINCIPLES OF OPERATION

It is helpful to think of the EF Sensor as a small radio transmitter and receiver combination (transceiver). There are both input and output connectors on the board used to connect the sensor to transmit and receive antennas (electrodes) which can be located at some distance from the sensor. These connections are made through two shielded (coaxial) cables. Shielded cables have an insulated center conductor with a metal foil and/or woven wire braid surrounding it. The use of coaxial cables allows the user to control the point at which the wire leaving the sensor begins to function as an antenna. It starts as soon as it leaves the shielded cable. See Chapter 4 for more information on cable selection and use.



The antenna electrodes can be composed of lengths of any type of wire (i.e. bare, insulated, stranded or solid), flat adhesive metal tape, metal window screen or ordinary kitchen aluminum foil to which the center conductor of the shielded cable has been connected. The type of wire or other material used depends on the type of field you wish to establish between them. The larger the electrodes, the greater the range. Smaller electrodes provide more precise detection.

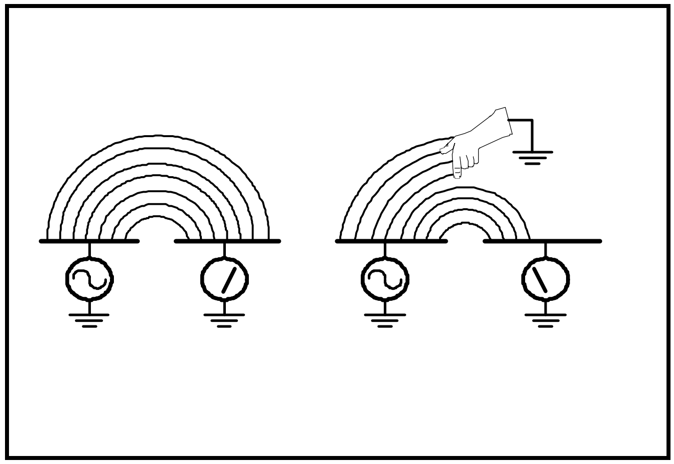
The figure to the right illustrates the electric field that is generated around and between two electrodes. The field lines emanate out in all directions, but the ones we are most interested in are the lines passing between the two points. *For the sensor to function, the body being sensed must intersect the field generated between the two electrodes.* You must therefore position the electrodes such that whatever it is you are trying to detect, will move into that field. Envision the electrodes as two 6 foot long wires taped vertically to either side of a door frame. In the illustration, you would be looking down on them from the ceiling above. They would appear as the points in the drawing with the field connecting them going across the door opening like iron filings between the poles of a bar magnet. Anyone walking through the door would enter the field. Using the same illustration, envision the electrodes as running down the opposite walls of a hallway at about waist height parallel to the floor. In the illustration, you would be looking down the hall with the field between the electrodes extending across the hallway between the walls. Anyone walking down that hall would enter the field. Similarly, electrodes placed on the opposite sides of a room could be used for full-room sensing.

Now envision an installation where the goal is to trigger a wall-mounted audio-visual display when a person walks up to it. One possibility would be to place the two electrodes vertically on either side of the screen. This will certainly work if the trigger distance is within 3-4 feet of the wall, because as you can see, the field does not move in a straight line between the electrodes. It bulges out in the middle. The amount of "bulge" is a function of the electrode separation distance. The further apart they are, the more bulge. But what if a series of displays prevented increasing the separation distance? An alternative would be to place an electrode under the screen running parallel to the floor. The other antenna could be up and behind the person--perhaps in the ceiling. This example illustrates more clearly why an understanding of the field behavior is important to successful application of the sensor.

To get technical, as the electrodes are moved farther apart, the field strength decreases. If the distance is doubled, the signal strength will be only one-quarter as strong (varies inversely to the distance cubed between the electrodes). Reductions in field strength can be compensated for by using larger electrodes up to the limits of the output amplifiers. You will have no problem driving antennas of 10-12 feet in length over separation distances of over 12 feet through 50 foot coaxial cables. The specific limits will depend on your particular situation. There are adjustments on the board for both transmitter power and receiver sensitivity.

Two Modes of Operation--Shunt Mode

Shunt Mode is the first of two categories of operation. The effect of objects entering the field between electrodes depends on their range and if they are grounded.



The figure to the right illustrates two pair of antenna electrodes. In this case, the electrodes are aluminum foil plates rather than wires, but the principles are the same. For each pair, the electrode on the left is radiating and the one on the right is receiving. The signal source is represented below the radiating plate by a sine wave source, and the strength of the signal being received by the plate on the right is shown by the meter indication.

When a hand, body or any other conductive object is placed in the field, an electric current will be induced in it. If that object is grounded, a portion of the radiated field will be shunted to ground. This is where the term "Shunt Mode" comes from. In Shunt Mode, the sensor is adjusted so that when there is no object in the field, the signal strength arriving at the receive electrode is just enough to cause a relay on the board to close. When an object enters the field, the signal strength is reduced, and the power to the relay is no longer enough to hold it closed. It opens and will remain open until the object exits the field.

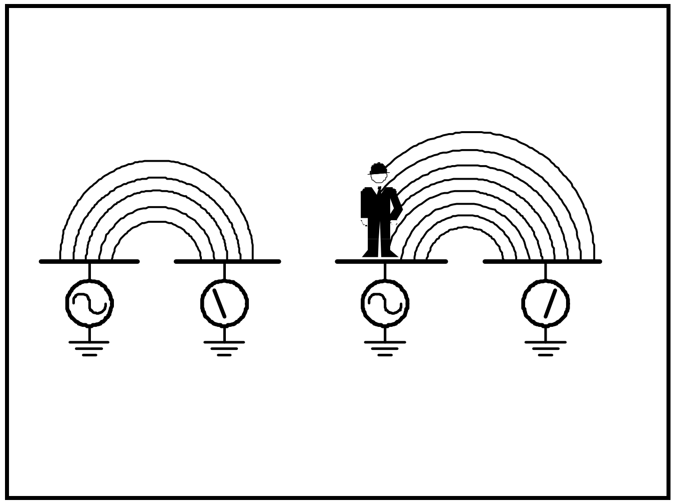
An important consideration for the use of Shunt Mode is that the object entering the field be grounded. If the object is not grounded, it is unlikely that it will draw off enough of the radiated signal to cause the relay to open. In the example on the previous page where we had two wires taped on either side of a doorframe to sense the entry of a person into a room, it is necessary that the person be walking on a floor which provides a good ground. All concrete slab floors meet this requirement. Their proximity to the earth and the frequent use of reinforcing bar or screens ensure this. Frequently, second floor commercial construction also provides a good ground because of the use of steel. It makes little difference what the floor covering is or what the person may be wearing on their feet. They can be wearing thick socks, shoes, and the floor can be covered with carpet, wood, rubber mats or any combination of these, and they will have little effect. The signal will be conducted through all of them to ground.

What about residential all-wood raised floor construction? Many homes, particularly in the East, are of this type. In these cases, to use shunt mode, it will probably be necessary to improve the ground plane. There are several ways to do this. In carpeted rooms, a piece of metal window screen or layered sheets of kitchen aluminum foil can be placed under the carpet and connected by a wire to any convenient earth ground. The grounding wire of a nearby electrical box or romex cable would a likely source. Special adhesive tape for making soldered connections to aluminum is available. Sources are provided in Chapter 4.

If the room is not carpeted, grounding materials can be tacked to the underside of the wood floor from under the structure. Although the need to apply special grounding does represent more effort, it will be compensated for by improved sensor performance due to the excellent ground it will provide. Both sensitivity and dynamic range will be increased. In fact, in cases of slab floor construction where you are trying to achieve the absolute maximum sensitivity to persons entering the field, improvement of the ground plane is an option.

Shunt Mode is the method to use for any application where you are attempting to sense people moving through a doorway, down a hallway, entering a room, or applications similar to these. But there are many applications where it is impossible to ground the sensed object. For these situations, Transmit Mode is the way to go. The worse the ground, the better it likes it.

Transmit Mode



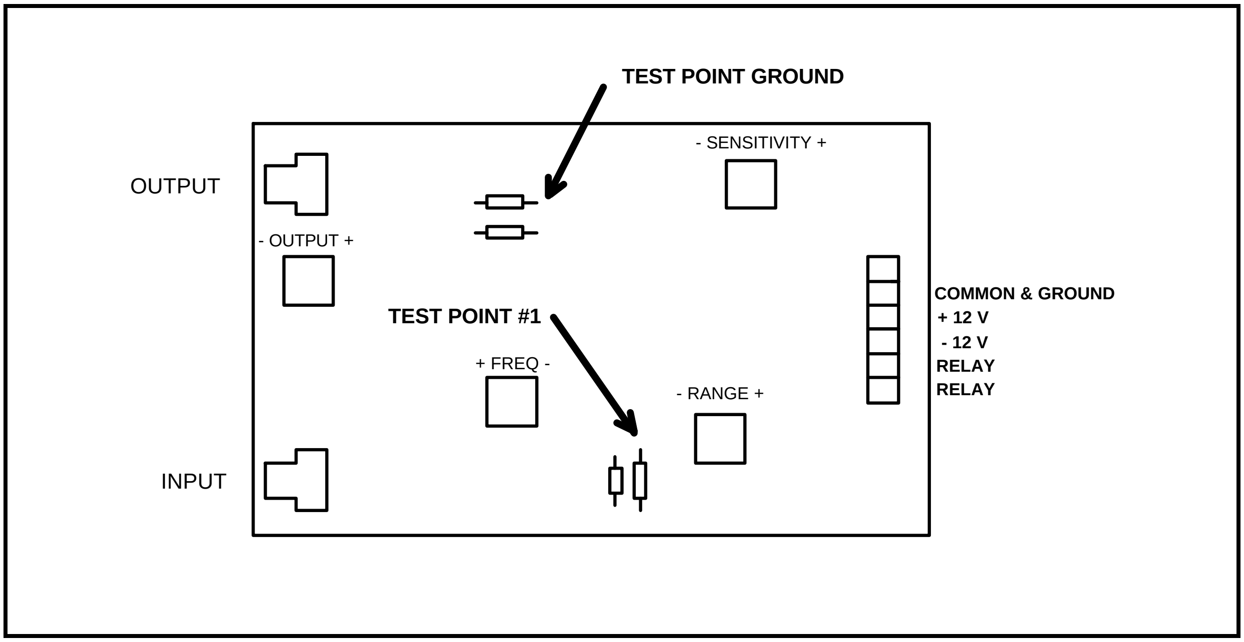
Referring to the figure on the right, when a person stands, sits, or is otherwise near the transmit electrode, the signal will be capacitively coupled into their body making the entire person a transmit electrode. The effect will actually be to make the transmitted signal *stronger*.

When a body first enters the field from a distance, it will attempt to shunt the radiated signal to ground. As the body gets closer to an electrode, the system changes from Shunt Mode to Transmit Mode. Actually both modes occur simultaneously. Some portion of the signal is always being coupled to the body and re-radiated to the receiver, but until the body is very close to the transmit electrode, the amount being shunted exceeds the amount being coupled and radiated.

To take advantage of this effect and operate in Transmit Mode, the EF Sensor relay is adjusted using a method just opposite from that used for Shunt Mode. When there is nothing in the field, the relay is adjusted so that it first closes but then the adjustment is backed off just to the point where it opens. At that point, any increase in signal would cause it to close. When a body enters the field from a distance, the field strength drops, but since the relay is already open, it has no effect. As the body gets closer and closer to one of the electrodes, the signal strength increases and the relay closes. It will remain closed until the body moves away. In practice it often makes no difference which of the two electrodes the body approaches because a better receiving antenna can often help as much as a better transmitting antenna.

Some obvious applications for Transmit Mode would be detecting the presence of a person on a bed, chair or couch. The two electrode wires can be stretched across the mattress from one side to the other under the bed pad at a separation distance of 2-3 feet. It is a simple matter to adjust the sensor so that the relay is open with no one on the bed but closes when a person lies across the two wires. Note that if an electric blanket is used, it will be necessary to make the final sensitivity adjustments with the blanket in place. Similar pairs of wires can be used under the cushions of a couch or chair.

CHAPTER 3 - TESTING AND TUNE UP



The above diagram illustrates the inputs, outputs and adjustments on the EF Sensor board. The Input (Receive) and Output (Transmit) jacks are on the left. They are RCA Phono jacks and will mate to commonly available coaxial cables such as shielded audio or RG6 antenna cable using an adapter. Chapter 4 will explain how to use these cables to make the necessary electrode connections. It is important to know which sensor jack is receive and which one is transmit and not get the cables going to them mixed up once you have completed the frequency peaking procedure to be described. In the procedure, the circuit frequency will be adjusted to compensate for the capacitive loading effect of the <u>receive</u> cable. Cable capacitance varies with type. Shielded audio cables have a higher capacitance per foot than RG6. For a given cable, the longer it is, the greater its capacitance and the lower the resulting operating frequency of the sensor. A lower operating frequency may reduce range but increase sensitivity depending on the application. The effects of operating frequency on range and detection ability are discussed in Chapter 4.

There are four (4) adjustment potentiometers (trimmers) on the board. They are labeled OUTPUT, FREQ (frequency), SENSITIVITY and RANGE. All have + and **-** signs to indicate what effect each direction of rotation will have. Turning the OUTPUT control clockwise (CW) toward + increases the transmitter signal strength. It should normally be left in the full CW position. The FREQ control is turned counter-clockwise (CCW) toward + to increase frequency. Both RANGE and SENSITIVITY would be turned full clockwise (CW) toward + to maximize the sensitivity and range just as you would turn the volume control on your radio in that direction to make it louder. Use a small screwdriver to adjust the trimmers. Do not turn them past the stop or they may be damaged.

A screw connector is provided on the right for ground, power, and the reed relay. An *earth* ground (third prong on power plug) is required in addition to a common power connection between + and **-** 12VDC. When using the PS-2 Power Supply, both earth ground (bare) and common (Black) go to the same terminal. These connections are made internally on the PS-1 Power Supply so only one wire (Green) will be going to the common/ground terminal.

In the center of the board are two test points labeled GRD and TP1. Each is the leg of a resistor. Prepare for the following test procedures by connecting the Negative lead from a Digital Voltmeter or other high impedance meter to the GRD test point. Connect the Positive lead to TP1. You will be looking for a DC Voltage in the range of 12V so set your meter accordingly. Don’t power up the sensor until told to do so.

Connect a continuity checker across the relay terminal lugs so that when the relay closes the checker buzzer will sound. If you only have one meter and you are using it to measure the voltage between the test points, see Question #5 in Chapter 6. Hook up the power supply including both earth ground and common, but don't plug it in yet.

Test #1: Initial Test

Connect insulated hook-up wire about 1 foot in length to each of the RCA phono jack center terminals. One will be the transmitting antenna and the other the receiving antenna. Place the two wires parallel to each other about 1-2 inches apart. Small test clips with wires attached to them are recommended for this purpose. Alternatively, you can tack-solder a short exposed section of the insulated wire to the center lead of the RCA phono plug where it exits on the solder side of the printed circuit board. IMPORTANT: Make sure that your connection to the RCA jack using either using the clip or solder method does not short to the outside grounded portion of the jack.

Set the trimmer controls as follows, carefully observing the direction of rotation:
1. OUTPUT = Full CW (+)
2. RANGE = Full CCW (-)
3. SENSITIVITY = Full CCW (-)

Now you can plug in the power supply, and slowly adjust FREQ back and forth until the relay closes and the buzzer sounds. This point will probably be near the CCW (+) end of the trimmer range. Now, for the first time, with the buzzer sounding, you should be reading between 11 and 12 VDC on the meter attached to the test points. Increase the separation distance between the electrodes when the buzzer is on and notice the effect. The buzzer should stop. Leaving the electrodes apart, increase the SENSITIVITY by rotating the control CW (+) just enough so the buzzer sounds again. Standing on a grounded floor, place your hand into the area between the electrodes. The buzzer should stop. Now you know that the sensor is working properly.

Test #2: Frequency Peaking

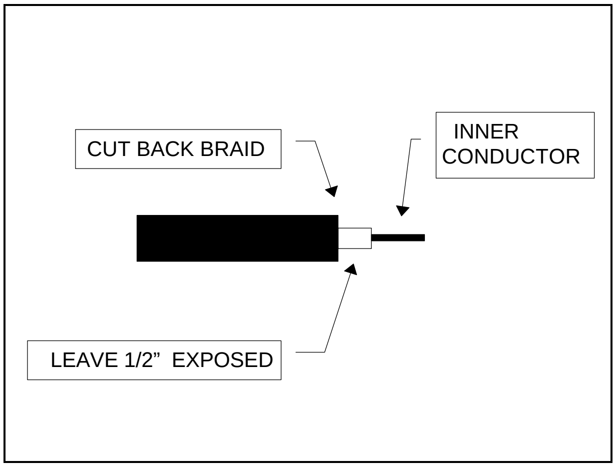
You will need to have the antenna electrodes connected to the sensor through the coaxial cables for this procedure. Using the method explained in Chapter 5, join 5 foot long antenna electrodes (solid or stranded wire) to the coaxial cables, and tape them up opposite sides of a wooden door frame. The electrodes should exit each coaxial cable about 6 inches from the floor. If you get the base of the antenna too close to the floor, part of the radiated signal will be drawn to ground. Stay out of the field until the frequency adjustment is complete. Leave the OUTPUT control at Full CW (+), but for this experiment, place both RANGE and SENSITIVITY at full CW (+). Connect both meters and the power supply as explained above. Plug in the power supply and slowly rotate the FREQ control back and forth until the relay closes. You will notice that there is a range of rotation of perhaps 30 degrees that causes the buzzer to sound. During the next step, you will refine that range to a few degrees.

Place the FREQ adjustment in the approximate middle of the range that keeps the buzzer on. Gradually reduce SENSITIVITY while watching the meter hooked to the test points. The meter reading should drop, and at some point, between 2 and 3 volts, the buzzer will stop. If you reach the full end of the SENSITIVITY adjustment range and the voltage has dropped but the buzzer is still on, leave it there, and turn the RANGE control CCW (-) until the buzzer stops. Back it off enough so that you can control the buzzer with the SENSITIVITY control. Once the buzzer is off, rotate the FREQ control *very slowly* back and forth until the voltage rises and the buzzer starts again. What you will find is that each time you reduce SENSITIVITY, the voltage peak achieved by adjustment of the FREQ control will become lower and sharper. At some point, it will become so sharp that the voltage will peak but the relay will no longer close. At that point you will know that your adjustment is as sharp as it is going to get.

Once the frequency is set, you can adjust the RANGE and SENSITIVITY controls until the relay just closes with no one in the field. When someone approaches the door, the relay will open. There are many combinations of electrodes, separation, and control settings. The guideline to follow is that once you have optimized the frequency setting, and you want the relay to open, begin by reducing SENSITIVITY, then RANGE, then OUTPUT in that order. OUTPUT power reductions should only be made as a last resort since they reduce the signal-to-noise ratio.

CHAPTER 4 - BUILDING ELECTRODES AND CABLES

There are two types of coaxial cable that can be used to connect antenna electrodes to the sensor: A) shielded audio/video cable of the type that comes with STEREO/VCR/TV and B) 75Ω RG6 TV antenna cable. The advantage of RG6 is that both signal loss and the capacitive loading affect on transmission frequency will be less (2.2db per 100' @ 100Mhz and 17.5 p*f* per foot). The disadvantage of RG6 is that it is thicker and less flexible. Use of audio cable should be restricted to runs under 12' if possible. If necessary, you can combine the two. When selecting audio cable, you need to look for more than just the right plug. Be careful not to use speaker cable by mistake. It has the right plugs, but the wires are arranged in tandem rather around a common axis. RG6 coax and shielded audio cable are available from Radio Shack. RG6 coax is sold by the foot or in a pre-terminated 50' roll 15-1548 @ $14.99. Be careful NOT to get RG58 or RG59. Adapter 278-252 @ $1.99 will mate the RG6 connector to an RCA plug. Shielded audio cable comes in 3,6 and 12' lengths. The 3' double is 42-2351 @ $3.99; the 3' single is 42-2366 $1.99. See the Support FAQ section at www.bik.com for more information on this subject.



Typically the antenna electrode will be simply a length of unshielded wire. To join it to the cable, begin by stripping the coax as shown in the diagram on the right. Remove at least one inch of the outer layer of insulation and the metal shield between it and the inner layer of insulation. Make sure you have cut back and removed every piece of the shield from where it exits the outer layer of insulation. Once you have done that, you can strip back the layer of insulation around the inner conductor leaving at least 1/2" of the insulation exposed. Insure that at no point does the shield come closer than 1/2" from the now exposed inner conductor. Preventing shorts is one reason, but equally important is that if it gets too close, even if it does not touch, it will cause the transmitted signal to be grounded before it even gets a chance to reach the antenna electrode. If you are using audio cable, the inner conductors can be delicate. The connection can be very easily broken unless some form of strain relief is provided. Applying multiple layers of progressively larger sizes of shrink tubing is one solution.

If your electrode is a metal foil or screen, strip back enough of the outer layer of insulation and shield so that no portion of the shield extends over the electrode. Maintain at least 1/2" of separation between the end of the shield and the beginning of the electrode material. Tape the wire to the electrode to provide strain relief. For foil electrodes, you will discover that copper wires cannot be soldered to aluminum. The solution is to use adhesive copper tape. The tape adheres well to aluminum foil and can be easily soldered to. An 18' roll of the 1/4" width is available from Newark Electronics 800-463-9275 (Stock No. 96F9287) for $8.86. If all you need is a 1 foot length, that is available at no charge from Russell Bik Design for a self-addressed stamped envelope.

In new construction, electrode wires can be hidden behind sheet rock. For existing construction, one alternative is to use alarm tape. This is the silver, adhesive tape about a quarter of an inch wide used to sense the breaking of glass. It has been replaced in most new installations with acoustic sensors, but it is still available in rolls from your local alarm supplier. Alarm tape is as thin as aluminum foil and is completely invisible under wallpaper or a coat of texturing or thick paint. In a typical installation, the tape (and this applies to wire electrodes also) would be run along the wall parallel to and about three feet above the floor. If run too close to the floor, the path of the emitted field will be downward into the ground rather than into the air and across the room to the other electrode running parallel to it on the opposite wall. Each run of tape would be terminated with a right angle turn downward toward the floor where it can be connected to the coaxial cable running to the sensor. The tape-to-cable connection and the coaxial cable itself can be hidden behind the floor molding.

CHAPTER 5 - TROUBLESHOOTING

The most common problem is forgetting that the sensor operates in two modes: Shunt and Transmit. Transmit is used only when the object being sensed is going to be approaching within less than 1 foot from the electrodes. Otherwise, use Shunt mode. Make sure you understand how to adjust the sensor for use in the mode you have selected. The way that you "switch" between the two modes is based solely on how you adjust the relay. In Transmit, it is adjusted to be *open* with no one in the field. In Shunt, it is adjusted to be *closed* with no one in the field.

A common problem is an inability to get the relay to open when a person enters the field in Shunt Mode. Go through the following checklist:

1. Has the frequency been peaked for the shielded receive cable being used?

2. Is the OUTPUT at maximum and are the SENSITIVITY and RANGE adjusted so that the relay *just closes* with no one in the field? If SENSITIVITY and RANGE are at minimum, and you can't get the relay to open at all, it may be because the electrodes are too large or too close together. Reduce OUTPUT only as a last resort. Consider reducing electrode size and/or increasing separation first. If you can get the relay to open when you reduce the above control settings but not when a person enters the field, it may mean that the person is not standing on a good ground. See Item #4 below. If SENSITIVITY and RANGE are at maximum and the relay won't close, it may be because one of the electrodes is too close to a ground or the sensor itself is not properly grounded. See Item #3 below.

3. Does the sensor have a *true earth ground* to its common terminal? If your building electrical system is properly wired, the ground terminal on your outlet is joined to a cold water pipe at the service panel. If uncertain, check continuity between your ground and a cold water pipe. The sensor is measuring the voltage difference between the electrodes and ground. If it is not properly grounded, the reference will "float".

4. Is the person you are trying to sense standing on a good ground or does it need to be improved? If you are trying to operate in Shunt Mode on a raised, all-wooden floor, it is likely that you will need to improve the ground plane by placing metal foil or a window screen under the carpet or floor and grounding it.

The sensor adjustments, the size and separation of the electrodes, and the grounding of both the sensor and the person in the field are all interactive. Once you get it setup for your application, it will stay where you put it and work reliably, but finding the right combination may require some experimentation. There is a relationship between the amount of experimentation required and the effort spent in advance understanding the operating principles and installation site requirements. Familiarization with the tune up procedures in a controlled environment such as on your workbench and an advance site survey are encouraged.

CHAPTER 6 - FREQUENTLY ASKED QUESTIONS

See Support on line at www.bik.com for the most complete and current list of FAQs

1. ***Can one sensor be used to cover an entire room ?*** Yes. In one experiment, two 10' lengths of wire were taped horizontally to the walls on either side of a 12' X 12' room containing a table and chairs. The distance of the wires from the floor was 3 feet. Using Shunt Mode, the sensitivity was adjusted so that the relay just closed with no one in the room. Whenever a person entered the room, the relay opened. It stayed open no matter where the person stood in the room or sat at the table. A seated person needs to remain in reasonably close proximity to ground to keep the sensor continuously triggered. If that person is seated on an all-wooden chair and raises *both* feet more than a few inches off the floor, the ground connection could be broken. If this happens, connect a piece of screen placed on the floor under the chair or simply a wire run down one of the legs, to another wire run under the seating cushion. This is only required for non-metal furniture.

If the installation were such that large metal objects are normally in the sensed field, they will reduce the dynamic range of the sensor. In other words, if you had a field normally filled with metal desks sitting on a grounded floor, to get the relay to close, it would be necessary to increase sensitivity to overcome the field-grounding affect of the desks. When a single person entered the field, the difference between the amount of field they grounded versus the desks might not be sufficient to cause the relay to open. In such a situation, the number of sensors required would need to be increased to establish multiple zones of detection. Another solution is to use a motion sensor covering the room in combination with proximity sensors covering seating areas or beds. This approach works very well.

2. ***Can more than one sensor be used in the same room ?*** Yes. Each sensor has a unique operating frequency based on the length of the cable joining it to the receive electrode. It is no more likely to be interfered with by another sensor than by your local AM radio station.

3. ***How do I get the relay to close (instead of open) when entering the field in shunt mode ?*** You will need to use a second relay. Although the relay on the board is rated at 1 Amp at 125VAC, it would be advisable to use it to control another relay that does the actual power switching if the amount of power being switched is more than a few watts. This approach will extend the life of the on-board relay and provide you with SPDT relay logic. Radio Shack sells 12VDC relays capable of handling up to 10 AMPS for $3.49, that would be one way to go. The PS-1 power supply also has a 5VDC output--another common relay voltage.

4. How can I interface the sensor to my computer or X10 system ? X10 is a good way to use the EF Sensor to switch high power lights and appliances. The Powerflash Interface PF284 is available from Radio Shack for under $20.00. It provides screw terminal low-voltage connection to the sensor. When the sensor is triggered, the Interface Module will send a signal out over the power line which can be used to control other X10 modules to turn lights and appliances on or off or to interface to more sophisticated home automation hardware designed to receive and process those signals. The advantage of the X10 Powerflash module is that it removes the need to run separate wiring, and there is a wide assortment of supporting hardware and software available.

5. I only have one meter. How can I adjust the test point voltage and listen for the relay continuity buzzer at the same time? An LED and 1,000 ohm voltage-dropping resistor are now included to solve this problem. Connect the short LED lead to the –12V terminal and the long lead to the adjacent RELAY terminal. Connect the 1,000 ohm resistor between the remaining RELAY terminal at the bottom of the terminal strip and the GRD terminal at the top of the terminal strip. The LED will illuminate when the relay closes.