Mike's TV and FM DX Page

PHASERS! - THE *WHOLE* STORY

Designed and manufactured by Andy Bolin and Dennis Jacob. Written by Andy Bolin

Andy's email : dxshack at consolidated dot net

Welcome to phasing! To the best of our knowledge, a radical yet virtually unexplored concept. By the time you've made it to the end of this literature you should be convinced that phasing is probably the greatest stunt to come along for TV and FM reception since the invention of the outdoor antenna!

As you look at this mound of information, you are probably asking yourself if you need to know this much about phasers to use one. The answer is NO, but it sure helps to have as much of an understanding of the subject as possible. Everyone should try to develope skills in thinking through various signal situations. If you can do that, you won't just be nulling signals-- you will find yourself peeking weak signals instead of nulling strong ones...removing adjacent channel splash...getting rid of ghosting on TV and even eliminating noise from power lines. Non-technical people should be able to skip over our technical text and still have a good enough understanding of phasing to install and use their own system. However, we will be inserting many of our own observations and comments along the way, so we suggest you skip nothing!

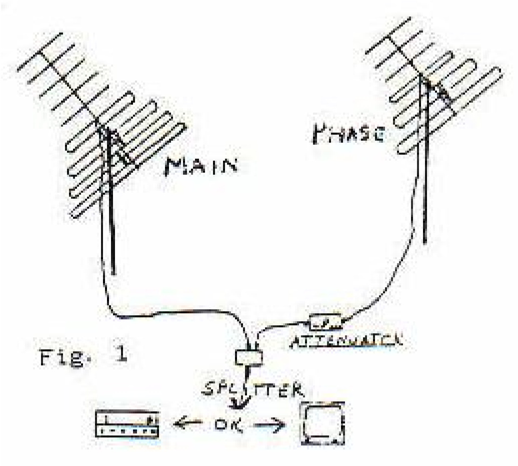

Figure 1 shows the basic phaser system. Notice this is nothing more than two antennas coupled through a two-way splitter/coupler (hooked in reverse) to the receiver. You can use the Radio Shack part number 15-1141 splitter or anything similar for these phaser applications.

STATEMENT #1. No matter how simple or complex the design of a phaser system, the point where the two incoming signals mix (the splitter) must always have identical signal strength on its inputs to achieve a null.

Notice in Fig 1 to meet the demands of the above statement, we have inserted an attenuator in line with one of our antennas. We suggest you use the Radio Shack part number 15-578 attenuator for this and all phasing applications. The type of antennas you use doesn't matter. If you want to use one small and one large FM antenna, that's fine. If you want to use one FM and one TV, that's fine, too. Since an attenuator will cut down on signal levels when inserted on the main antennas trunk line, we insert it on the antenna with the least amount of gain. This means the only signal loss to the system is the loss of the two-way coupler.

For phasing to work properly, antennas should be spaced horizontally more than one wavelength apart. We are assuming you are using separate rotors. When the antennas rotated in a direction where their elements are closest to one another, the spacing should not be closer than 10 feet for FM, 17 feet for VHF TV channels 2-6 and 8 feet for VHF TV channels 7-13. Anything less than one wavelength spacing usually results in reduced signal levels, not nulls. Anything less than one-half wavelength is useless.

Now, let's actually use the "phaser" of Fig 1. On FM, let's assume you aim your main antenna to the side or away from a 50kw station at a distance of 50 miles (90km). That is, aim it where you want to create a null. Now you turn the rotor on the other (phase) antenna in all directions. At the same time the rotor is turning, you turn the attenuator up and down. This may or may not give you a null. Chances are against it, but it's worth a try. If it fails, move the main antenna 10 degrees amd try it again. It may or may not work, but odds will always be against you. I dub this the "pot luck" circuit. You turn a pot and hope for luck, and in six months hope you haven't worn your rotor out.

The above paragraph is all it takes for basic phasing. It also offers us the opportunity to explain why phasing works.

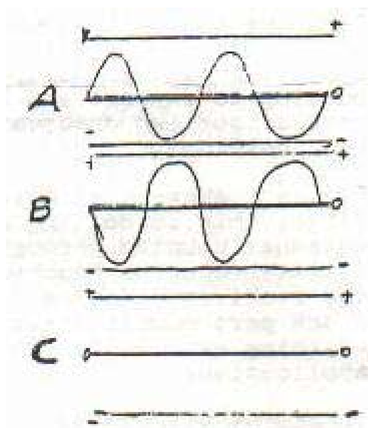

Fig. 2

Figure 2 explains this in very simple terms. Suppose for a moment you stand on the roof of your home and wave a magic wand that lets you visibly see a signal from just one FM or TV station. You could call the signal an AC voltage since it has a positive and negative component to it. Since you now have the power of visibly seeing the signal, suppose we place an antenna at a point where the signal is at its most positive point...point A on Fig 2. Now suppose we put another antenna at its most negative point...point B on Fig 2. Now let's combine the two signals together with our antenna coupler. Since we have combined our two antennas, the voltage output of our coupler would be the same as if we laid figures 2A and 2B on top of one another. That is, at any point in time if antenna 2A sees positive, the 2B antenna sees the same thing negative. If you add these positive and negative voltages together at any point in time, the output would always be zero volts, and zero volts means (point C on Fig 2)...no signal, a null! As you look at Figure 2, it should no be apparent why statement #1 is imperative. If the signal at the coupler from both antennas isn't identical, the voltages would add to something other than zero.

Getting back to our "pot luck" system. In this case by our turning the attenuator at the same time as rotating the phase antenna we are trying to hit a point where the signals are the same in level (with the help of the attenuator), while trying to find a spot that is out of phase with the use of our rotating antenna.

There is no statistical way to calculate what percentage of time the "pot luck" system will work. But in order for it to work at all in our example, the phase antenna must at least have as much gain while aimed into the undesired station as the main antenna has aimed where you are trying to create a null. This means the more gain the phase antenna, the better the odds. All in all, don't plan on anything better than a 1 in 20 chance.

The reason for the "pot luck" system working so poorly is the fact that the only element to the system controlling phase is the phase antenna itself. There is a much better way!

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Those AC signals we talked about in Fig 2 are also present in the coax. If we were to cut a piece of coax off of one antenna (but not the other), it would be the same thing as moving your finger from left to right over Figure 2A or 2B by whatever distance. The point is a spot would be reachedwhere 2A and 2B are out of phase and we have a null by simply snipping off pieces of coax. Instead of snipping coax, you could make up coax jumper cables of various lengths to splice in line as needed. But splicing in various cable lengths is still putting us in one fixed phase. We need something tunable; we need a phase box.

IMPORTANT COMMENTARY. When it comes to an actual phase box, a key question is how much control of the phase spectrum does the box have? Perfection is to go from in phase to out of phase to back in phase (360 degrees). When we began our research, we found out real quick that almost any circuit you cared to dream up would have some control over the phase spectrum, but it was very limited. Things that worked on paper won't work in reality. Once you've gone somewhere around +/- 30degrees, if the impedance mismatch doesn't get you, the loading effects will. Subsequently, we gave up on the idea of a single stage (tuned or untuned...ganged or unganged) circuit getting control over the entire 360 degree spectrum. To the best of our knowledge, it can't be done...but it CAN be done with a two stage tuned ciucuit. While we were in the process of researching our phase box, a commercially available model showed up for sale in a CATV trade magazine.

The manufacturer is charging over $500 for the unit. Since the unit only has one control on it for phase, we assume it doesn't have more than +/- 30 degrees of control. A few months ago another company introduced their phase box in a trade magazine. They even tell you if you cannot get a null to splice in different lengths of coax to get their box to work. Since we are dealing with a new concept, there is no printed literature on this subject anywhere. It is alot of research time and a lot of research money spent. These people are in business, and we don't condemn them at all for charging over $500. What we are trying to do is say "buyer beware". If you decide to purchase a phase box from someone be sure to ask these two questions. First, how much control over the phase spectrum does the box have? Second, since it is being sold mainly to CATV companies, it may be a "set and forget" model; meaning you use it a few hundred times and it wears out because it was made using sleazy tuning coils that weren't meant to be fooled with all the time.

What we have done is on a hobbyist basis. So we can afford to build and sell our 360 degree phaser for a hobbyist price. But, since we have a lot of research money to recuperate, we do not sell or give schematics for our box. Besides, you are dealing with tuned circuits that are tough to build and you wouldn't have a working model to compare against it anyway. This is as good a time as any to say, since sales are slow, that there are three areas we did not get researched. We have not tried a UHF model. We have not tried to build a channel 2-6 and 7-13 phaser in a common box. Various horizontal distances between antennas as well as staggered antennas.

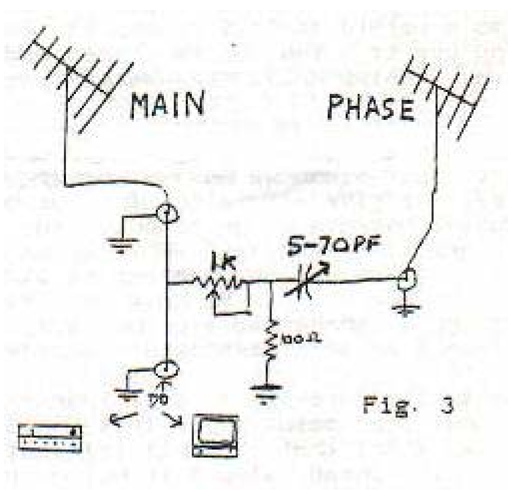

Figure 3 shows a +/- 30 degree phaser. In reality, I am sure it has more than 30 degrees of control, but the results may be poor past that point. For that reason, we dub this circuit our "1/6 of a phase box" since that is what it is! But, this little circuit is a real work horse. It's cheap, simple to build, has a built in attenuator and a few other things, too! So we will be nice and not call it a "1/6th phaser". We will instead call it a "phase tilter".

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When it comes to a real phaser, the phase antenna system you use is important. For the +/- 30 degree unit, we suggest the same antenna setup as for the phaser we sell, so simply read the information.

IMPORTANT NOTE: From this point on, we will call the process of statement #1 "balancing the line". How you accomplish it is up to you. If we are talking about an FM receiver with one antenna unplugged, if you get a signal meter reading of S3, and then you switch antennas, then that antenna must also read close to an S3 or there will be NO null. (Note: when the main antenna is unplugged, rotate phasing knob or knobs for maximum S meter reading). In the case of TV, simply match the graininess or snow in the video. Think this through! If the phase antenna is real low in gain compared to the main antenna, the only way to get a null is to aim the phase antenna at the station causing the interference and the main antenna to the side or back of the interfering station and hope that the phase antenna has enough gain to get an S3. If it does not, the only thing you could do is add an ateenuator to the main antenna. But, now suppose you use the same make and model of phase antenna at the same vertical height as the main antenna. You would never have to aim the phase antenna in one direction and the main antenna in another, just aim them both on the same heading. It doesn't require you to "think" how to aim the phase antenna. Also, with the phase and main antenna having the same gain, you can aim directly into semi-locals and vaporize them! We will discuss system performance and antenna directivity later, but for now understand how important phase atenna gain is.

On TV, you are looking at the snow level to balance the line. Inthis case, you can get away with using different makes and models of mast mounted amplifiers. You can even get away with an amplifier on one antenna and not the other. But on FM you are looking at an S meter. So of course if you put a noisy amplifier on one antenna and not the other, you can't balance the line. On FM use no mast mounted amplifiers or use the exact same make and model on both antennas.

For those who read schematics, notice our phase tilter of Fig. 3 is not a tuned circuit. All phasing is actually being done by the capacitor. Therefore, this circuit has an advantage over a tuned circuit. That is, it has a very broad bandwidth. Without any modifications this circuit works from 54 to 216 mhz, which is all of VHF-TV and FM. A tuned circuit is limited to +/- 30 mhz, but it can do a 360 degree phase shift. So it's a nice trade-off. Fig 3 will give a nice phase tilt across the wide range of frequencies, but it requires the user to try as many as six different lengths of coax to get a null.

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Construction of Fig 3 is straight forward and hassle free. The capacitor should be an air variable plate type; that is, at least a "medium" in physical size and is the isolated from ground type. If possible, install the capacitor in the chassis first and check the capacitance to ground with a digital capacitor checker. If capacitance is higher than 6pf, the tilter will not function properly. Meaning your capacitor needs better isolation from ground.

Notice Fig 3 has a built in attenuator on the phase antenna. This setup is assuming the phase antenna has poor gain compared to the main antenna and that the phase antenna will always be aimed at the station causing the interference while the main antenna is aimed somewhere else. But if the phase antenna is high gain and you always want to aim it in the same direction as the main antenna, leave the bilt in atttenuator set for minimum resistance and put the 15-578 attenuator on the main antenna's line.

As we have already pointed out, on a phase tilter if you cannot get a null, splice a coax jumper in one of the antenna trunk lines. On VHF-TV, since we are talking about a wide range of frequencies the length of coax is pretty unpredictable. You would need one length for channel 2 and another for channel 13. All you can do is try a foot or so at a time, and hope you score a hit. FM, only being 20mhz wide is simple to calculate. From whatever phase point your tilter happens to be at once installed, you can move the nulls as follows. To move your null 30 degrees, add a 6.5 inch jumper. For 60 degrees, add a 11 inch jumper. For 90 degrees, add a 19.5 inch jumper. For 120 degrees, add a 26.5 inch jumper. For 150 degrees add a 32.5 inch jumper and for 180 degrees add a 39 inch jumper. These lengths are calculated solely for 75 ohm coax with a velocity of propagation 66%. Of course if you use coax with any other specs you will have to recalculate the above lengths. Basically, these specs are for most Beldon RG/59 and 11 coax. Nothing from Radio Shack has these specs. Please consult your coax catalogs before making any jumpers. Good Luck!

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THE 360 DEGREE PHASER

This is it - the 360 degree phaser! Imagine being able to aim into a semi-local and null it. Turn yur antennas ten degrees and null it again. Turn your antennas another ten degrees and null it again. And do it again and again and again all the way around the entire 360 degree phase spectrum! That's a 360 degree phaser, null anter null without the messing with coax jumpers! Once you've learned these few nulling techniques you'll be nulling stations in less than ten seconds!

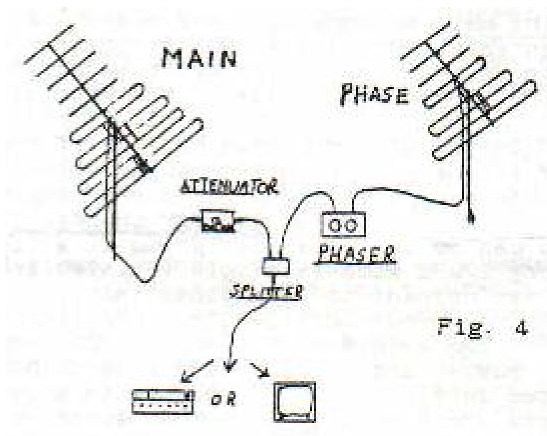

Fig. 4

Fig 4 assumes the phase antenna is high gain. If it's not, you won't be able to balance the line on the same antenna heading as the main antenna, so move the attenuator to the phase antenna. Then, always aim the phase antenna at the station causing the trouble and the main where you want the null. This is giving up the ability to aim both antennas in identical directions, but with a very low gain antenna there is no other alternative.

Here are step-by-step instructions for balancing the line with your 360 degree phaser as shown in Fig 4. (1) disconnect the main antenna. (2) rotate the knobs on the phaser for maximum S meter readings, or by viewing the TV signal strength. Note the reading. (3) reconnect the main antenna and disconnect the phase antenna. Adjust the attenuator for the same reading or level as was obtained at the end of step (2). (5) reconnect the phase antenna and begin lowering the signal levels by going back and forth with the two knobs on the phase box. That's it. We will describe a "quick null" method in a moment. But keep in mind that the "balance the line" method is the most reliable.

The above will always work assuming the antennas involved are close in gain. But on FM a high gain antenna shows more of a noise figure than a low gain antenna on the S meter. So if you are using a high and low gain antenna, once you've balancd the line you may need to add a small amount of attenuation to the main antenna to get the null.

You must use the "balance the line" approach when strong signals are involved. Our definition of a strong signal in this case would be aimed into 20kw at 50 miles (80km) for FM assuming a high gain system. Since your S meter will be slammed, one way to accomplish the null task is to sneek up on it. In other words, with the strong signal detuned, use the "balance the line" method. then, tune a little closer and keep trying to lower the signal for the null. If you are technically inclined, the best way to deal with this is to modify your S meter ciurcuit with a control for turning down those strong readings on locals. Then you can use the "balance the line" method with just one pass at any signal level no matter how strong it is.

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Here is a way to deal with strong TV signals and another way to handle strong FM signals if you don't want to modify your S meter circuit. Add a 15-578 attenuator to th phase antenna. You now have an attenuator on goth antennas. On TV, using the "balance the line" method, turn up the attenuator on one antenna until you just see a grainy picture. Switch antennas and adjust the other attenuator for a grainy picture(the same signal level). Adjust the controls on your phase box for the null. Now you can turn the controls up on the two attenuators by an equal amount (until one attenuator is at maximum level) and you will go back into the null. What we are doing here is over attenuating both antennas so we can get an S meter reading, or see a grainy picture. Adjusting phaser, then turning both attenuators back up by the same amount puts us back into null without touching the phase box.

By now you should have a good understanding of phasers and how they work. An attenuator adjusts signal strength. A phaser adjusts phase. By making the signal levels identical with the attenuator, then adjusting the phase box, you should be able to obtain the desired peaked or nulled results and that is what this is all about!

When using the 360 degree phaser and signals weaker than described above, there is a shortcut that gets you out of balancing the line. We call this the Quick Null method. This is assuming both the main and phase antennas are aimed in the same direction and the phase antenna system has within 10db as much signal as the main antenna system. With your 15-578 set for minimum attenuation its knob pointer points at the 5 o'clock position. Just try the two controls on the phase box to see if you get a null. If not, turn the attenuator knob to point to the 3 o'clock position and try the knobs on the phase box again. If not, try the attenuator in the 1 o'clock position and try the knobs on the phase box again. Using this system with just a little practice you will be abl to "nuke" stuff in less than 10 seconds!

The only thing missing from Fig 4 is a way to switch between antennas for balancing the line on those strong signal nulls. Of course you could unscrew the coax at the coupler. There are two better ways. You can use push-on quick connectors such as Radio Shack part number 278-218, or use a high isolation A/B switch. Never use the push button type antenna switch because of poor isolation. The sideway movement sype slider switch is usually best. Just come up with something rated as good as 50db isolation. There are also some sneaky methods as well. Such as turning off the AC on the mast mounted amplifiers. You could even mount some antenna switching relays in your system...just think it through.

If you will be using two phase boxes, one box for channels 2-6 and another for 7-13, space them with a 3 foot jumper connecting them in series. There will be some minor interaction between controls on the two different boxes.

As a rule, both models of TV phasers will work for FM, but the attenuator will have to be set substantially higher, like on the order of 10db. The FM model will only work on channel 6. This is not written in stone since the phasers are hand built.

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Is your phaser working properly? Installation of the 360 degree phaser is as pictured in Fig 4 except for whatever you decide to use s an antenna switcher for balancing the line. Once everything is installed, we suggest you try a few different cable lengths spliced only into the phase antenna side of the line to see if you can get the phaser to perform any better. There are three warning signs to alert you that a coax jumper needs to be added: (1) You can assume soething is wrong if a station will null while a different station in the same town with the same power will not null. (2) The pointers on the knobs on your phase box usually point down when you reach null. This is an indication that the coax is almost out of range. (3) The left control on the phase box does not seem to do much, or performs sluggishly, when it should have the same sharp peaks as the right control has. In all cases try adding, or removing, 17 inches of coax from the phase antenna side for channels 2-6 and FM, 10 inches for channels 7-13. Ideally the knobs should point near up on the majority of your nulls and both controls should have sharp peaking. If you are still not getting correct or enough nulls try coax jumpers of various lengths. This is not a critical situation and once completed you will not have to mess with jumpers again.

Again assuming near identical antenna systems. You can use your 360 degree phaser for more than just nulling stations. You can aim both antennas at a weak signal that is not being interfered with and peak the signal with the two controls on the phase box. This usually helps lift weak stations up to usable levels. Also the peaking technique can be used for those nasty violent fading signals. Your 360 degree phaser will usually stabilize fading signals by at least 50%. If you have power line noise we suggest using the quick null method described above for eliminating that problem.

We hope it is clear how important phase antenna system gain is. It is having near (within say 12db) the same gain as the main antenna is the most important feature of the system you install. But I feel another statement coming on.

STATEMENT #2. Once you have made it into a null, the best directivity you will have will be the worst directivity of the two antennas! Read on.

An example for statement 2. Let us suppose (from central Illinois) I want to listen to Columbus, Ohio on 97.1 with Indianapolis on the same frequency in the same direction. If both antennas are high gain FM antennas I should be able to do it. But what if the phase antenna is a less directional VHF Tv antenna, even if it has as much gain as the FM antenna? The answer is, even though both antennas are aimed into Indianapolis, the most likely thing I will hear is St. Louis, MO off the back of the system. It is not difficult to understand why the system works the way it does. Look what would happen if Indianapolis went off the air. If both antennas were aimed east, and just the FM antenna is hooked up it would receive Columbus. But when just the less directional TV antenna is hooked up, it would receive St. Louis off the back of the antenna. So, a phaser can make a station look as if it is not on the air, but when in a null the directivity you have will be the worst directivity of the two antennas involved.

The above is to prove a point. The more directional the two antennas are, the better off you are. But still a VHF and an FM antenna work very well together on FM. In fact, it works well enough that I would not spend the money of a second FM antenna if I had a good TV antenna already installed. Of course, the TV antenna will have to have good gain across the entire FM band.

Let's take statement 2 to the ultimate extreme. If you used a five element FM antenna at 20 feet, and for phasing put a non-directional single element S antenna at 60 feet, then once in a null that null would be non-directional. Whatever the next strongest signal was, in any direction, is the one you would receive.

Anticipating Results. This brings us to the next part of our discussion. Results vary dramatically for TV and FM. Also, horizontal spacing is a contributing factor. On FM, you should be able to aim into 10kw at 50 miles and not be able to tell it is on the air. For 20-50kw stations at 50 miles it really depends on how well the station gets out. As a rule, you can get a null on a 50kw at 50 mile station if another signal is behind the semi, but it will probably not stay tuned. It may drift. Don't let anything stop you from trying! Even if you cannot get a null aimed into at 50kw does not mean you cannot get a hull on that 50kw station at 15 miles when aimed to the side or back of it. When they are this strong, you may make or you may not.

TV is another story since you are dealing with separate audio andvideo frequencies. You already know the nulls you get by just using one antenna usually do not result in "nuked" signals. You dump the audio or video but generally not both at the same time. A phaser will usually work in the same manner. You will dump one or you will dump the other, but don't plan on both at the same time. As a rule, using the 360 degree phaser will get you an audio/video null together perhaps 1 in 3 times. The stronger the signal, the less likely, while the weaker signals (over 80mi/130km) does not have a bad chance of a complete audio/video null. In most cases you can have a choice of whether you tune in the video or the audio. Otherwide the story is the same as FM. If you aim into a 50 miler you should be able to dump the audio or video for the next TV station up the road.

A channe 2-13 antenna works fine for TV, but statement 2 spplies, so you are much better off running a channel 2-6 phaser to a pair of channel 2-6 cut antennas. The same goes for channels 7-13. There is one thing you want to be sure not to do. Whatever you do, do not put up a pair of channel 2-13 antennas in which one antenna has substantially better gain at channels 2-6 while the other has better gain at channels 7-13!

STATEMENT #3. It is always worth keeping in mind that you cannot achieve a null if you allow the phase antenna to have more gain than the main antenna. That is why we designate the phase antenna as the antenna with the least, or equal, gain.

Looking at Fig 4, it would be assumed that if both antennas were identical, spaced approximately one wavelength part and on common rotor, that the signal strength would always be the same on both antennas no matter what. This would theoretically mean no more attenuators! Well, it does not work because of antenna interaction. In fact, there is a pattern to the interaction. If your system is aimed north, south, east or west, the pattern makes the shape of the letter X, meaning that you do not have to use the attenuator unless you are in one of the points of the letter X. Then you may have to crank the attenuator up to 2 db or so. The point is that you cannot get out of using the attenuator even with common rotor horizonta stacking. The only disadvantage to common rotor stacking is the wind and ice loading. Of course, as with regular horizontal stacking, the horizontal mast must be made of a non-metallic material. For now we assume you will get good results with any spacing in which the elements from the two antenna involved do not come closer than a wavelength to each other: 10 feet for FM, 17 feet for TV.

Whether you use common rotor stacking or an antenna at 50 feet on one side of your home and another antenna at 25 feet on the other side of your home, you can expect astonishing results with your 350 degree phaser!

Finally, an answer to the most common question we get. Can a phaser be used to stop overload? The answer is yes assuming the overload is in the receiver and not the mast mounted amplifier. But it does not make sense to use a phaser because it stops you from using your rotor. Once you have turned your rotor 2 degrees you are out of your null. Even finding the null on something so close that is is causing overload takes a considerable length of time. In reality you do not get a null on something this strong. The signal turns distorted. It strips the carrier and leaves you the sidebands. The way to handle overload is with asingle frequency trap. On TV use a 15db trap with a 2mhz bandwidth. On FM a 15db trap with a 500khz bandwidth works fine. The nice thing about traps is they can be made with negligible insertion loss so you can string them together in series.

In summary, we have gone through a lot of text to simply say have identical signals from any two horizontal antennas spaced fore than a wavelength apart, run them through a phase box and you will probably get a null. That is the bottom line. Just because we went through all kinds of variables in our text should not be a reason for you to be confused.

Even if you choose not to purchase a 360 degree phaser, we sincerely hope you will do the next best thing and try our phase tilter (Fig 3).

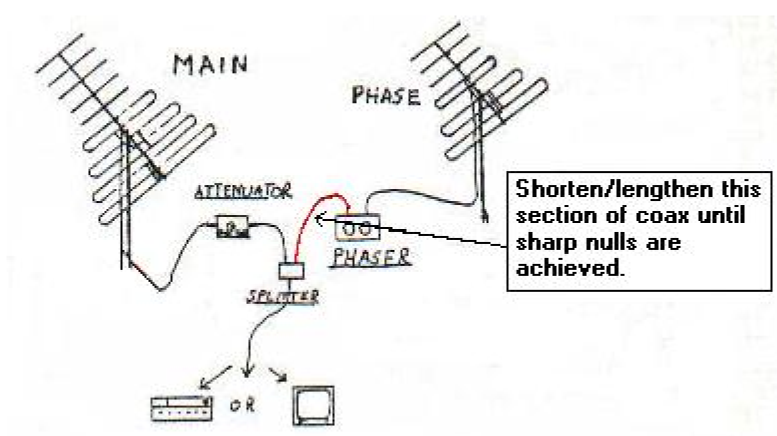
Andy Bolin

Charleston, Illinois USA

September 1991

PHASER UPDATE...OCTOBER 1993.

Regarding Phaser - page 3 first paragraph. Is your phaser working properly? In many phaser installations the cable length is far more critical than we originally realized. Some do-it-yourselfers report just a few inches of coax placed anwhere before the coupler can be the difference between reduced signal levels versus very deep nulls. On the other hand, many installers find all but a few lengths work properly. Of course, changing cable length before the coupler (even if just an inch) changes the time it takes for the signal to reach/mix in the coupler and thereby has a major effect on the phase of the system. The reason this is so pronounced on some phaser installations and not others is assumed to be antenna spacing. We want to advise you to be prepared to experiment with as many different cable lengths as needed for installation. On FM you should be able to aim your antennas directly into 6 to 10kw stations at 50 miles and not be able to tell that the station is on the air, 80 miles for TV. Once the right length is found you should have deep nulls on all such powered stations withoug again playing with coax jumpers. If you are not getting these kinds of nulls, something is wrong! And that something is probably your cable length. As mentioned in your text, you cannot get these deep nulls with antenna spacing of less than one wavelength.



**For more information on phase box availability and pricing, contact the author, Andy Bolin, Charleston, IL
at dxshack at gmail dot com**

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This page revised Oct 5, 2008