A PHASED FIELD ANTENNA

Bill Graham, VE3ETK

INTRODUCTION

In early 2004 I got excited about the developments in antennae – that is an antenna where the E (electric) and H (magnetic) fields were brought into phase to produce improved reception and transmission. The difficulty with published information was that the designs were primarily created for the broadcast industry, or used broadcast concepts that didn't take into account the needs of the radio amateur. It became clear that a new approach was required that would meet the needs of the amateur, and yet incorporate the principles of Poynting's work with phasing.

Antennas that are designed to phase both the E and H fields require you to give up a lot of the traditional thinking you may have stored up in your mind based on conventional dipoles, etc. You must open your mind to new thinking – remember, it is the final result that really matters. Often when one thinks of phasing the thought is only about electrical phase. There is also physical phase, where two (or more) items are moved in relation to each other. If these items carry electromagnetic fields, then those fields are also moved.

The goals were to create a small 20M antenna that could be mounted in an attic or on a balcony, that would compare with a dipole for reception and transmission, and have as much of the E field and H field as possible <u>pointed</u> in the same direction – that is, physically phased. Of course, this antenna could also be mounted atop a tower.

This article describes how these goals were achieved and how to construct a working antenna – one that is easily rotatable and only 2 feet in diameter on 20 metres.

Two years of research and development were involved, with each development leading to another (and generally) better design. My first attempt was designated the EH TURBO, followed a little later by the PFp (A prototype for Phased Fields), then the PF-2, 3, AND now the PF4-20. Let me give you a little background on these antennas so that you might understand how the final result came about:

EH TURBO**:** Worked very well and phased E and H fields properly by physically shifting the position of the coils, where most of the magnetic energy is created in a short antenna. However, while the noise reduction was good, the performance was 2 db down from a dipole.

PFp: Designed for 40M and Field Day use, the radiator was #14 wire stretched out horizontally as with a typical dipole. We made some nice contacts, but performance was not as good as we obtained from the 40M dipole.

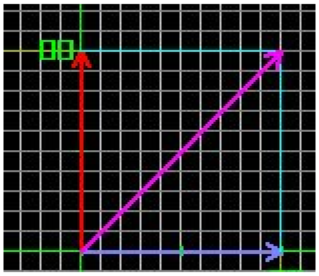
PF2: Designed for 20M, it also worked well as to noise reduction and reception/transmission, but it was still 2 db down from a dipole. Mathematical comparison with the PFp showed the need to put a greater surface area of metal in the air.

PF3: Also for 20M, and was designed to use coax for the resonant part of the antenna. This was a failure due to the fact that some currents bucked in the coax coil and heated things up, causing resonant shifts.

It just goes to prove that you have to have failures to have success!

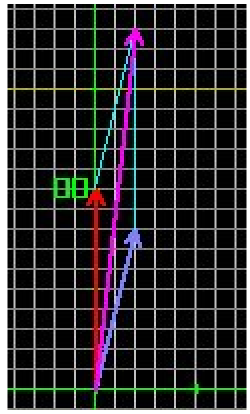
The picture above is an example of early PF work and the style of the construction. It is hanging from a tree for purposes of testing. Note that the coils are at 90 degrees to the radiators.
This is a PF2 with 3/4" copper pipe for ‘radiators’.

Before moving on to the finished product I want to cover something about the phasing of the E and H fields and how it can truly improve signals. If you have read any material about phasing your radiated energy, you will have read about a key factor called the Poynting Vector. Here is a simple, straightforward explanation, using vector analysis.

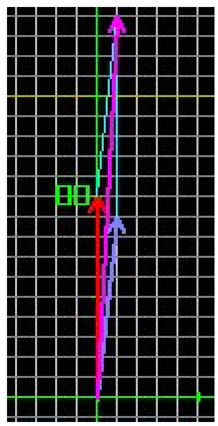


This drawing shows the normal radiation of a dipole with the E (Electric) Field in red, and the H (Magnetic) Field in blue. With 200 watts coming out of the transmitter each field radiates 100 watts, but they are 90 degrees out of phase, as is normal with a dipole antenna. The purple line is the vector sum of this energy, with a total radiated power of 145 watts at 45 degrees.

To clarify what happens when we bring the fields into phase; the next diagram shows the H field shifted 84 degrees (now at 6 degrees), and an improved (focused) output of 180 watts.



And now an example of an almost perfect phase shift:



The output is now 190 watts at 97 degrees.   If the output is improved to this amount, the reception is improved equally.

If that isn't enough to convince you that Phased Fields work, consider the following. Rayleigh-Carson Theorem: In 1929 John R. Carson added an extension to a theory previously put forward by Rayleigh. Put in its simplest form, it states that the current and voltage created in one antenna will appear identically in a second antenna. Several years later it was discovered that this was true, except where radio waves had bounced off of the ionosphere. Then it is only true when the magnetic field is precisely aligned relative to the direction of propagation (the E field). Should two stations both be using Phased Field antenna then they can expect an even greater result.

Finally, a note about understanding the generation of the E and H fields from a single source – your transmitter. The 'wire' used in any antenna produces both E and H fields, 90 degrees out of electric phase with each other. In most antennas that is the radiated energy. When a coil is introduced to create a short antenna, it also produces E and H fields. However, the H (magnetic) field in a coil is concentrated such that the strongest magnetic radiation is from the ends of the coil. This is not a figure 8 pattern though, but sort of sausage shaped. A dipole construction has the strongest electric radiation at right angles to the wire or radiator, and is a figure-8 pattern.

The next design was created to have as much of both fields as is possible aligned so that they 'point' in the same direction, and the dipole portion is curved to assist with that concentration of energy.

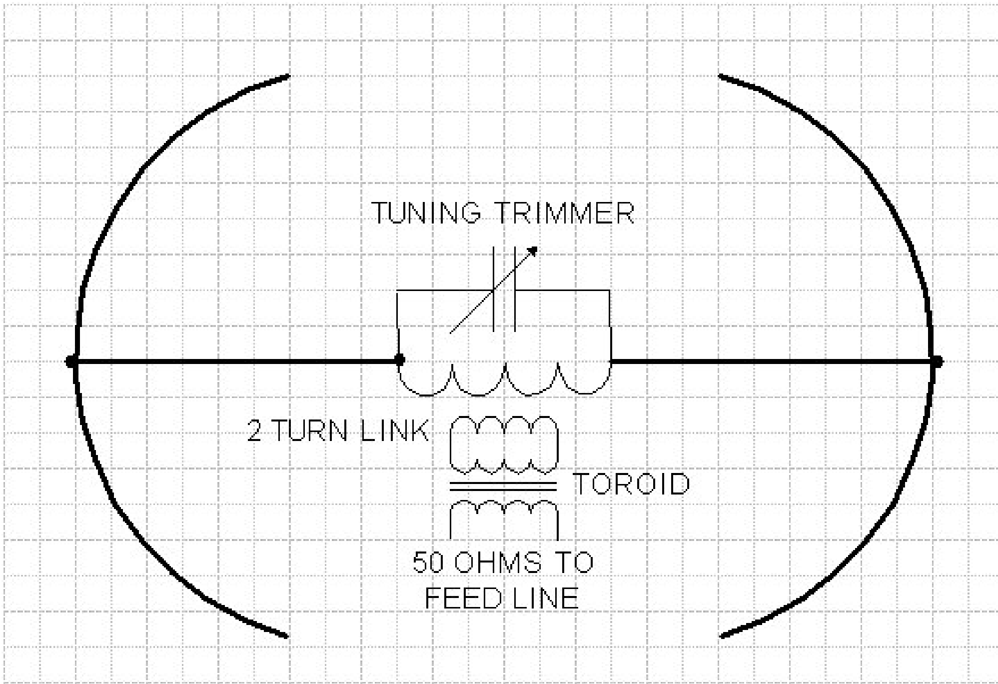
AND NOW, THE PF4-20 - A REAL WINNER!

THE VE3ETK PF4-20 ANTENNA

The PF4-20 is designed for the 20-M band, and has been developed from all the things learned from earlier design work and testing. Part of the thinking you must adjust to is that an antenna doesn't have to be a wire stretched out for a ½ wavelength; an antenna simply has to be resonant. Other factors do come into play and one of these is the surface area of metal used. The use of mesh for the radiators came from experimentation which showed that there MUST BE A LARGE SURFACE OF METAL IN THE AIR - in fact, the equivalent surface area of a half wave dipole made of #14 wire.

In the PF4 version the coil is made on 1.9" OD PVC pipe, which is also used to form the support for the antenna. The coil consists of 15½ turns of #14 solid plastic covered wire. The position of the coil can be seen in the picture above. It's the 'stub' sticking out the back, moving the maximum H field into line with the maximum E field. The diameter of the coil related to its length is important to obtain a good Q factor, which plays a major part in this antenna matching the performance of a ½ wave dipole. The combination of the size of the mesh and the spacing between the two parts provides capacitance, and along with the inductance of the coils provides the needed resonance.

Construction is simple; just follow the wiring diagram and the picture.



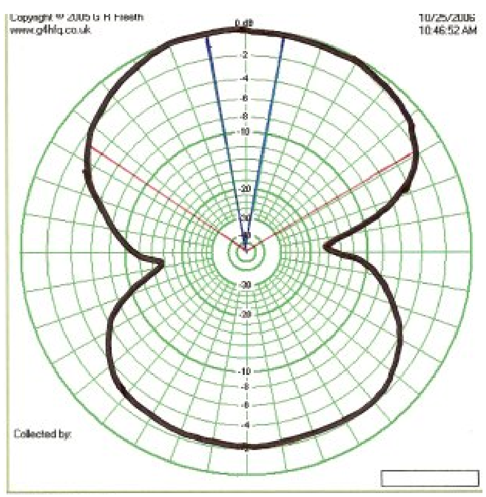
In the next picture, you can also see a weatherproof box mounted to the support, behind the coil, which contains a 5-pf variable capacitor in this design that permits easily shifting the center of resonance to your favorite band frequency. The capacitor has a plate spacing of 1/4" because of the high voltage that is created at this point. Because 5 pf will shift tuning right across the 20-meter band all wiring is made very rigid for frequency stability. Note (in the picture below) the 1/8" brass rod used to connect the coil to the feed rod. Also note that the feed loop is NOT properly positioned in this picture. It must be centered on the coil.

The radiation elements are made of mesh screening such as is used for eve-trough covers. The sections are 3' long and for the 20-meter antenna are cut 2" wide. Each end is bent over 2 inches to permit mounting to the insulators, and provide capacitance. The center of each radiator has the paint removed and is solidly connected to the support/feed rods, which are 1/4" threaded galvanized rod. At the top and bottom there is no need to remove the paint as no connection is being made. The curvature controls the pattern to some extent and in part, permits the antenna to have a low radiation angle at half of the normal height for a 20M antenna. The insulators are 4" long ceramic and are pushed through a tight hole in the PVC support. If you don't have ceramic insulators, 1/2" PVC pipe with caps glued to the ends will work well.

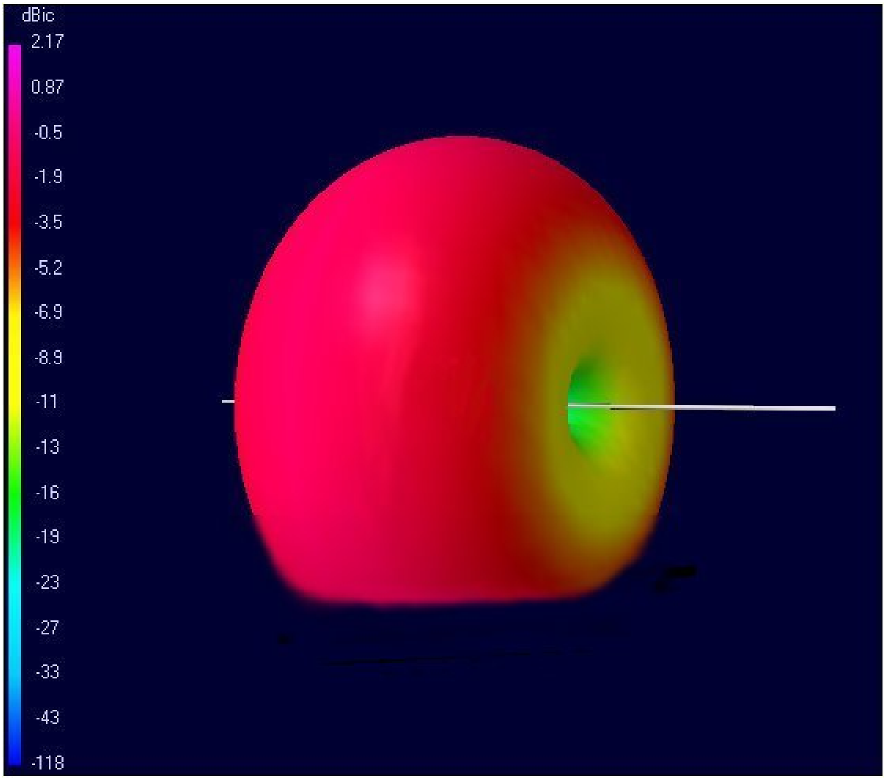
The toroid is a T106-2, and is also mounted in a weatherproof box (cover off in the picture). It is wound bifilar to make a balun, with #20 enamel wire, 32 1/2 turns for the 50-Ohm side (coax) and 22 1/2 turns for the antenna side, although this may vary due to differences in your coupling. Coupling by coil was chosen because direct connection of the balun to the coil resulted in a drop in Q. The balun also severely reduces any radiation from the feed line. The coupling coil is 2 turns of #14 stranded insulated wire and needs to be placed at the exact center of the resonating coil. A great, free toroid calculator can be found at http://www.dl5swb.de

The antenna pattern is like a fat doughnut. If the antenna is mounted as I describe here (loop upright with insulators top and bottom) then the doughnut is standing upright with the holes to the sides. The metal support rods can be visualized as running through the doughnut hole, and the doughnut passing through the space created by the insulators. The bottom side of this upright doughnut pattern will be somewhat squished at the bottom unless the antenna is mounted about 60 feet up, which is not a very important thing to do because the DXer is looking for pickup and transmission at low angles, and this antenna provides that when it is mounted twenty feet above ground. If the antenna is rotated clockwise so that the insulators are at each side then the pattern will be omni-directional as the doughnut is now the same as if it were lying on a plate. If the antenna were mounted so that the loop is parallel to the ground then the pattern will be like the first description, but the pickup from the top would have less magnetic field sensitivity. The coil would then have to be repositioned so that it is wound on the support arm, but this would affect the symmetry of the pattern.

When the antenna was finished I created a plot of the pattern, using a signal generator in the far field. The red lines show the 3 db down points, and this results in a “beam” width of 115 degrees. The blue lines show what I describe later as the “area of clarity”.



The nulls are 15 db deep at the center of the pattern. The next picture will show an approximated 3D pattern. It is approximated from gathered data, as this type of antenna cannot be modeled properly in 4NEC2. This is a clear case, though, of an antenna that will provide a low angle (15 deg.) of reception and transmission. This low angle at a height of 20 feet occurs because the antenna is so small that little of the energy reflecting back from ground strikes the antenna – the normal cause of pattern distortion.



If signals are arriving at a very low angle, or a very high angle it will be obvious that the nulls will not be as great as with those coming from middle elevations. I have, however, nulled out a kilowatt station that was about 300 miles away, and at near right angles from the DX station I was contacting.

RESULTS**:** Mounted at 20' up the PF4 is matching everything that my dipole can do, PLUS I can rotate the PF4, and therefore I can hear stations on the PF4 that I can't on the dipole, opening the possibility of making contact. Stations closer than 500 miles are occasionally stronger on the dipole due to the angle at which the signal arrives. However, in that close they are so strong that 2 db is irrelevant. On DX the PF4 surpasses the dipole every time. During the recent period of non-existent sunspots I have had some good DX contacts: CT1, CO8, J79, F6; and one mid afternoon a ZS6. Nulls to the sides of at least 15 db have been measured, and noise is generally 9 db down from the dipole, all of which indicates that the E and H fields are phased. A bonus to this is that just when the antenna is almost pointed directly at the signal, the signal becomes clearer. I don't mean stronger, but clearer! This effect calls for a long explanation, but simply put is a direct result of proper energy phasing of BOTH the E and H fields.

STABILITY**:** The PF4-20 has been tested with an MFJ-259 during hot days (25C) and during cold winter days (-15C), and during very windy days with drenching rain. In all cases the frequency center of 14.2 MHz had almost no drift, while my dipole showed as much a 100 KHz. Snow and ice have not accumulated on the mesh.

TIPS FOR TUNING UP A PF ANTENNA**:**
- Create the antenna with no balun, but include the link turns, placing them exactly at the center of the coil.
- Use an antenna meter (such as an MFJ 259). The SWR may look very bad but that's not valid at the moment. It is the resonance you're checking now.
- If you included a trimmer capacitor, place it in the center of its range.
- Adjust the coil turn spacing, and/or the number of turns until resonance is achieved. Secure the turns so that they do not return to their previous place. Hot glue works well for this job.
- Read the impedance. Link coil turns may now be added and the turns increased or decreased to come close to 50 ohms. As whole turns must be made, if you cannot get an exact 50 ohms go on the low side.
- Now design the balun to match this impedance on the antenna side, and 50 ohms on the coax side. Remember that when making baluns for antenna, put 5 times as many turns on the form as calculated.
- Connect the balun and make any small adjustments to the antenna coil, link coil, and balun turns required to get a 50 ohm match and low SWR on the input (in this order), measuring on the far end of the coax.
- If necessary, repeat coil adjustments, and slight adjustment to the trimmer capacitor to place resonance at your favorite band frequency. With repeated trimming and tuning it will be possible to achieve 1.1:1 SWR at the chosen center frequency.

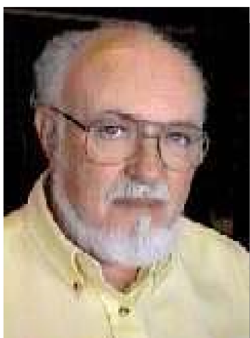
To encourage hams to try the PF4 on other bands the following table gives calculated values for the various parts. These values are approximates and will depend somewhat on your construction. The coil and the total capacitance of the construction must resonate at the desired operating frequency. For the larger diameter coils, a sleeve will need to be fitted to the PVC pipe coming from the T fitting. The diameter to length ratios for the coils should fall between 1:0.5 and 1:1.5 to achieve a good Q.

BAND	CIRCUMFERENCE	DIAMETER	MESH	MESH	COIL	CAPACITANCE	COIL	WIRE TURNS	LINK	END BEND	GAP
METRES	FEET	FEET	WIDTH	per SIDE	uH	to resonate	DIA.	#14 SOLID	TURNS	(makes C)	INCHES
20	6.2	2	2"	1, 3' piece/side	7.2	21 pf	1.9"	16	2 - #14	2"	4
40	6.2	2	4"	1, 3' piece/side	14	35 pf	1.9"	30	3 - #14	4"	4
80	12.6	4	4"	2, 3' piece/side	53	35 pf	3"	35	4 - #14	4"	5
160	18.8	6	6"	3, 3' piece/side	142	55 pf	4"	48	6 - #14	5"	6

The paint needs to be completely removed at the mesh joins when several pieces are used per side, and I suggest clamping these joins in place with 2 pieces of aluminum and bolts.

Summary**:** Through care and diligent testing at each phase of development a small 20 metre antenna has been created that compares to or exceeds the performance of a standard dipole for the same band. It does this when mounted 20 feet above ground and provides a low angle of radiation. Field strength meter tests (with a special adapter for detecting the magnetic field) have shown that both the E and H fields are pointed in the same direction, with little radiation to the sides.
'On the Air' tests have shown that the noise from local sources is at least 6db down from the dipole. At times the noise is so low that an annoying factor comes into play – I can hear stations when there is no hope of them hearing me under the propagation conditions at that time.

The antenna design has been copyrighted, but I am making it available for Radio Amateurs to use for non-profit purposes. I would be delighted to hear from those who have completed antennas and are using them on the ham bands. I can be contacted at ve3etk@rac.ca . Those with a commercial purpose need to make arrangements directly with me. **–30-**



ABOUT THE AUTHOR

Bill Graham, VE3ETK, worked at CFPL-TV as a Production Technician in the 1950's. He moved to CFTO-TV as an Audio Engineer, then to CHYM-AM/FM in the mid 1960's to serve as Chief Engineer.

His first radio license was issued in 1964. The years that followed were busy with consulting work and designing radio and television studios, culminating with a six-week stint in Singapore. Now retired, he enjoys all aspects of Amateur Radio.