



FREQUENTLY ASKED QUESTIONS

Welcome to the fractal antenna FAQ. Since fractal antennas (more specifically fractal element antennas (FEA)) are still an exotic and unknown option to many we believe this FAQ will be helpful. All the antennas shown are either [patented](#) or patent pending.

Q: Do you sell your designs?

A: Although antenna design is a big part of what we do, we are not a 'design house'. Our customers get solutions from us by delivery of product or by licensing. We do not provide 'work for hire' for antennas. Typically NRE charges are required for applications, because of the need for custom designs that work best for the form factor and environment.

Q: Why can't I just go to another company or university which works on fractal antenna designs?

A: Fractal Antenna Systems, Inc. provides fractal element antennas—exclusively. As Dr. Steven Best, President of the IEEE-APS has said publicly: "Nathan Cohen invented fractal antennas" -- our founder invented fractal antennas on 1988; published the first fractal antenna paper; and resolutely reduced the invention(s) to practice, thereby establishing the priority date on fractal element antennas. Patent filings date back to 1995. Our patents are free and clear and not in dispute. We invented fractal element antennas, we control the patents, and we are the exclusive source. For example, in the US, here are the patents which make it happen:

- USP 8253639 "Wideband Electromagnetic cloaking systems "
- USP 7999754 "Fractal counterpoise, groundplane, loads and resonators"
- USP 7973732 "Wide-band Vehicular antenna"
- USP 7830319 "Wideband Antenna Systems for Garments"
- USP 7750856 "Fractal Antennas and Fractal Resonators"
- USP 7705798 "Fractal counterpoise, groundplane, loads and resonators"
- USP 7701396 "Wide-band fractal antenna"
- USP 7659862 " Antenna System for Radio Frequency Identification"
- USP 7456799 "Wideband Vehicular Antenna"
- USP 7345642 "Antenna System for Radio Frequency Identification"
- USP 7256751 "Fractal Antennas and Fractal Resonators"
- USP 7215290 "Fractal counterpoise, groundplane, loads and resonators"

- USP 7190318 "Wide-band fractal antenna"
- USP 7145513 "Tuning fractal antennas and fractal resonators"
- USP 7126537 "Cylindrical conformable antenna on a planar substrate"
- USP 7019695 "Fractal antenna ground counterpoise, ground planes, and loading elements and microstrip patch antennas with fractal structure"
- USP 6985122 "Antenna System for Radio Frequency Identification"
- USP 6476766 "Fractal antenna ground counterpoise, ground planes, and loading elements and microstrip patch antennas with fractal structure"
- USP 6452553 "Fractal antennas and fractal resonators"
- USP 6445352 "Cylindrical conformable antenna on a planar substrate"
- USP 6140975 "Fractal antenna ground counterpoise, ground planes, and loading elements"
- USP 6127977 "Microstrip patch antenna with fractal structure"
- USP 6104349 "Tuning fractal antennas and fractal resonators"

Although we do license our technologies we have not authorized making, using, offering, importing/exporting, and/or sales thru foreign antenna companies. Kindly check if you have questions regarding sales or another source. We'd love to hear from you. Universities are not companies—that's our job. Theirs is education and research, isn't it? They certainly have no authority to sell or license you a design that is covered by others' patents.

Q: What is a fractal?

A: Fractals are 'broken curves'. They are a class of geometry that has been defined and popularized through the efforts of Benoit Mandelbrot and many others. They break into two main geometric types: deterministic; and random (chaotic). Random fractals are quite familiar and many look like random walks (Brownian motion); dendrites; or lightning bolts. Deterministic fractals take a 'motif' or 'generator' and apply it on successive size scales. Usually fractals are described as being 'self-similar', or 'self-symmetric'.

Q: What is an iteration? Doesn't a fractal have to go on forever to be a fractal?

A: An iteration is an application of the motif on a given size scale. Mathematicians usually refer to fractals as having n-iterations where n is taken to infinity. In fact, no graphic or physical representation of a fractal is capable of meeting this criteria. Physicists, computer scientists, and engineers have adopted the less constraining—and realistic—description of fractals as having a finite number of iterations. Certainly one needs at least two to claim the self similar aspect of fractals.

Q: Someone said you have a "skunk works" lab. Is this true?

A: We conduct research and product development in antennas and electromagnetics for our customers. We succeed at high risk projects. Our work defines the state of the art.

We are not affiliated with the Lockheed-Martin Skunk Works, which is an aviation facility.

Q: If fractal antennas are so good then why don't I see them in use?

A: Our antennas are widely used in applications across many industries, and military; government and security/public safety applications. It would be a rare time that you will 'see' our antennas, as they tend to be embedded inside

products or under radomes, for example. Our new Customer Spotlight series showcases some recent examples where our product 'wins' easily give the customer the Fractal Advantage(TM).

Q: Do fractals have any practical use (irrespective of antennas)?

A: Fractals have been applied as a descriptor of many physical structures such as terrain; clouds; vegetables; trees; anatomical organs; galactic clusters; lightning; and so on. They have been applied most successfully in engineering as a means of image compression and image enhancers. Fractal antennas are the most successful hardware implementation of fractal geometry.

Q: What is the “FRAGO” and why is it important?

A: Our Fractal Genetic Optimizer is a computer-based optimizing tool which we use to help identify the best fractal designs for a given antenna or electronics problem. It uses a genetic algorithm (see Haupt and Haupt, 1996, Practical Genetic Algorithms, Wiley) to help find these best designs. At the core of our proprietary approach is a process using a fractal coding to compress the genome for a dramatic speedup of the search process, as well as a PC cluster. We operate anywhere from 100-1000 times faster than other GA based antenna optimizers and can investigate at a rate of close to 2 million antennas a month with a rack of 16 PC's. FRAGO proves invaluable as a means to help customize an antenna need, for example. It is both a methodology and solution which goes beyond the trial and error needed to explore the huge design space of fractal geometric shapes. We are the only ones with FRAGO: we pioneered it ([Cohen](#) published the theory in 1997) and built it. And, we debugged it to make it work!

Q: What is a fractal element antenna (FEA)?

A: An FEA is an antenna (as opposed to an array) which has been shaped in a fractal fashion. This can either be through bending or shaping a volume or introducing holes.

Q: How were FEA discovered?

A: Fractal elements have been around for a very long time—but were not discussed as such. The log periodic array element of Isbell and DuHamel is clearly a fractal. Log periodics have been an important antenna design class for 50 years. The home TV antenna is a variation of this idea. Twenty years ago, Landstorfer and Sacher, using optimization approaches, came up with randomly bent antenna designs which are clearly random fractals—but again not discussed as such.

In 1988, [Dr. Nathan Cohen](#) built the first bona fide FEA. After years of building upon a knowledge base of FEA, with very modest resources, Cohen was ready to report some results. In October 1994, Cohen first publicly reported his results (at a radio convention), defining FEA and elaborating on their characteristics, such as multiband and broadband capabilities; shrinking of size; and so on. In August, 1995 Cohen published the very first FEA article. This included modeling and measurement data on multiband and broadband capabilities; shrinkage; and so on. An independent corroboration of some FEA properties by a university group in Spain was submitted only two months later and published in January 1996.

Because the basic science of FEA is so easy to demonstrate, it has caught on like wildfire—even high school students have won science fairs by

demonstrating fractal antennas. At this time there are over 200 articles published on FEA; major technical and scientific symposia have sessions on FEA; and over 100 independent research groups, across the globe, have or are conducting research on FEA. The science of FEA is now well established (see for example, a discussion of the corroboration by a UCLA group) in the mainstream of electromagnetics and engineering. All this happened in less than a decade from first discussion to recognition and acceptance—and it started with the humble bending of a piece of wire.

Q: I would like to know something about the schooling and background of the inventor. Could you provide a brief biography?

A: See the bio for [Dr. Nathan Cohen](#).

Q: What does fractalizing an antenna do?

A: The benefits depend on the fractal applied, frequency of interest, and so on. In general the fractal parts produces 'fractal loading' and makes the antenna smaller for a given frequency of use. Practical shrinkage of 2-4 times are realizable for acceptable performance. Surprisingly high performance is attained. Multiband behavior is manifest at non-harmonic frequencies, while some bands are broadened. At the higher frequencies the FEA is extremely and naturally broad band and can be made frequency independent without a log periodic geometry. Shrunk, very wideband FEA are possible. Arrays naturally benefit as well, as the arrangement of elements must be defined by 'Hohlfeld-Cohen-Rumsey' (HCR) conditions for frequency invariance. Phasing and polarization control are also attainable in FEA.

Q: Did you guys invent the fractal capacitor? Is there some advantage? What is a fractal resonator?

A: Scientists have been discussing fractals as capacitors now for nearly two decades. Liu's 1985 paper (Phys Rev.Let.,55,529) clearly shows a fractal capacitor built from a Cantor set. It sets the date of relevant prior art.

Nathan Cohen first looked at fractal capacitors in 1988 and included commonly known structures such as Koch islands. He found that near/at DC, and only near/at DC, a fractal structure can approximate a capacitor and thus there can be bona fide fractal capacitors. They are a little hard to make for these applications, and the thickness of the foil or trace material sets a limit to the practical advantage. Voltage gradients are also an issue and fractal capacitors are likely to pit easily over time—not what you want in any powered application!

However, at RF, the complexity of a fractal structure cannot be described simply as a 'C' in a 'LC' or 'RLC' circuit. It is an 'LC' or 'RLC' circuit and thus is defined as a fractal resonator. We thus recognized that a fractal capacitor was of limited interest or viability, but a fractal 'LC' circuit was important. Dr. Cohen first described the idea of a fractal resonator in his 1995 seminal paper. Additional disclosure occurred with the publication, in 1997, of one of our PCT applications (which is pending; watch for updates). It is protected by our patents and covered in patents pending. Our invention of fractal resonators establishes priority and defines what is now the prior art.

Think of a fractal resonator as a non-radiating, or poorly radiating, fractal antenna and you'll get the idea of the possibilities. Remember, all antennas are themselves RLC circuits.

Q: I understand that fractals have been used to solve an old problem from Maxwell's Equations. What is that?

A: In 1999, Fractal's Nathan Cohen published an article solving a basic problem: What are the requirements to make antennas frequency invariant? A later article by Robert Hohlfeld and Nathan Cohen then analytically showed that you need origin and self symmetry (self similarity) for this to occur in Maxwell's Equations. The implications are profound for antenna design, as a previous but less universal explanation by Victor Rumsey, made nearly 50 years ago, was shown to not be the total picture. The necessary and sufficient conditions for frequency invariance have been dubbed 'HCR Conditions', after the three contributors to solving this age old problem.

Q: If a FEA shrinks an antenna, how can it still work well?

A: It is well known that physical limitations impose severe field strength restrictions on electrically small antennas. And, when FEA are chosen to be very small (compared to a wavelength) they perform poorly—like all such small antennas. However, at the top side of the electrically small regime (say shrunk 2-4 times) FEA perform extremely efficiently and practically exceed other methods of antenna loading, including top loading.

Q: What are some other benefits of FEA?

A: FEA are self-loading so no antenna parts, such as coils and capacitors, are needed to make them resonant. In addition they often do not require any matching circuitry for their multiband or broadband capabilities. In effect the fractal design 'does the work', thus lowering the cost and increasing the reliability compared to other options.

Q: What types of designs benefit from fractal application?

A: FEA are an across-the-board option in antenna design and are applicable to any type of antenna such as: dipoles; monopoles; helices; patches; and many others.

Q: What frequencies and types of FEA are presently available?

A: We specialize at present on 900MHz, PCS, and WLAN applications. In addition, our line of wideband products have unique capabilities that are available no where else and we have antennas that work over moderate and wide bandwidths. We also have successfully met customer needs from 5 MHz to 20 GHz.

Q: How can I decide if FEA meet my application?

A: The first step in the process is to [contact us](#). Please note that we specialize in custom orders.

Q: Do you provide FEA or are they available from other vendors?

A: Fractal Antenna Systems, Inc., meets the needs of its customers by providing antenna solutions. We can provide the antenna as a component (often customized) or license the applicable technology as needed. Our antenna solutions are not available from other vendors.

Q: I experimented with a Hilbert curve fractal antenna and tested it, based on some claims about uses for mobile and handheld uses. It small but works very poorly as an antenna. Why?

A: There are a near infinite number of possible fractal antennas. While all of them share certain attributes, such as shrinkage; broad bandedness at higher resonances; and so on, only a very few are good or great antennas for a

particular application or frequency. Many researchers have not taken the trouble to consider the issue at hand: 'what problem is being solved'? Instead, they often choose a well-known fractal geometric design and report its RF properties. This served the field well in its infancy, but not its present maturity. That's why we've spent over 30 man-years of manual effort and then optimization-directed searching to find the very best fractal antennas for desired applications, with great success. We are indeed practical: we enjoy solving application problems. We have resisted publishing fractal antenna taxonomy as this fails to contribute to the true science of fractal antennas, and is worthless in exploring practical novelty from an inventive sense. In other words, it doesn't benefit our customers. We do not publish articles at the 'minimum publishable unit'. All of our publications have exposed basic insight into fractal antennas and how they work.

For small sized antennas, the Hilbert curve doesn't make the cut. At higher iterations it has the unusual attribute of being its own 'Faraday shield' and is a remarkably poor radiator. Its radiation cancels in the far field. Peano curves are close behind as poor, small radiators. A better description might be as 'fractal resonators'; see US patent 6452553. You may wish to ask your citation source why the Hilbert curve was chosen and described as a useful antenna and pose the question: what was the problem to be solved?

Q: How is a fractal antenna better than a meander (crank-line) antenna?

A: Antennas made of repeating sections are not new. The first of these 'meander antennas' is the ever popular spring, or a 'Wheeler helix', now over 50 years old. It is a three dimensional version. Two dimensional ones look like Grecian frescos or rug borders. Antennas engineers refer to these meanders as 'crank-line antennas', or CLA's.

Electrically, CLA's are uniform, discrete and repeating reactive loads, and can be replaced as an equivalent circuit by a series of the same valued reactive component. As such, the benefit is that the height of the antenna is shortened, just as with FEA. But because CLA's are limited by the repetition of the same sized geometric pattern, they do not have the chance to be shaped to best produce the reactive loads needed for best performance and multiple frequency operation. Basically, they get by, but have never been shown to be the best in performance for smaller antennas with multiple band needs.

On the other hand, FEA are, by definition, easily shaped, just by changing motifs and iterations. An FEA takes advantage of the freed-up design space that a CLA cannot possibly have, to get the best out of the least form factor.

Most meander antennas are off-patent, despite any statements to the contrary. These off-patent antennas are freely available to any and all firms.

Our firm sees no impediment to giving customers CLA antennas from these off-patent inventions—we just haven't found that they meet the need, as FEA options do better for their applications.

We have tested many meander antennas, and never found one that solves an application problem better than the respective FEA solution.

THE WORLD'S SMALLEST, HIGHEST PERFORMANCE WIDEBAND & MULTIBAND ANTENNAS