FRACTALS FOR ELECTRONIC APPLICATIONS

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FRACTALS

The discovery of fractals is usually bestowed upon IBM Researcher Benoit Mandelbrot in 1976. It involved calculations that could only be achieved by an intensive iteration process performed by computers…

Fractal – "broken, fragmented, irregular"

"I coined *fractal* from the Latin adjective *fractus*. The corresponding Latin verb *frangere* means "to break" to create irregular fragments. It is therefore sensible - and how appropriate for our need ! - that, in addition to "fragmented" (as in *fraction* or *refraction*), *fractus* should also mean "irregular", both meanings being preserved in *fragment*. "

Benoit Mandelbrot : The fractal Geometry of Nature, 1982

- Euclid geometry: cold and dry
- Nature: complex, irregular, fragmented

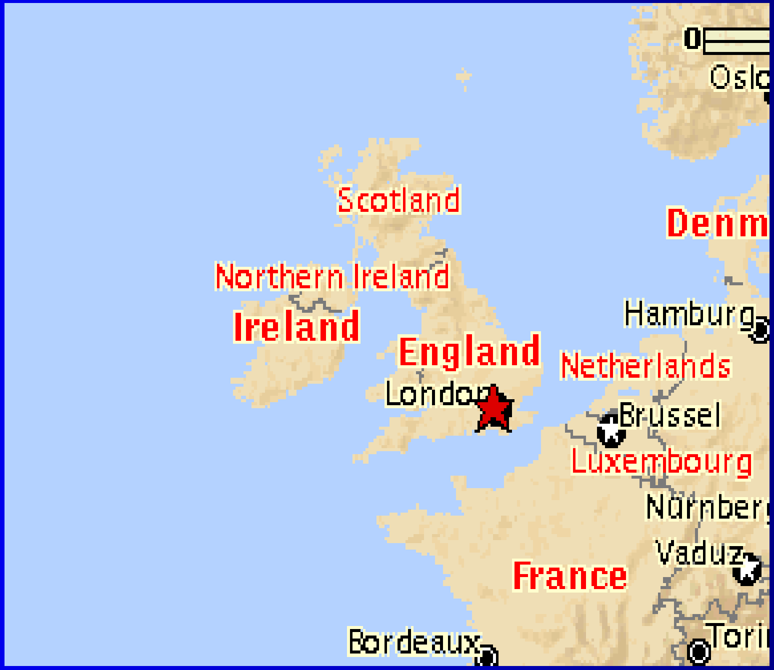
"Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line." We are confronted with „rough" and „smooth" !!

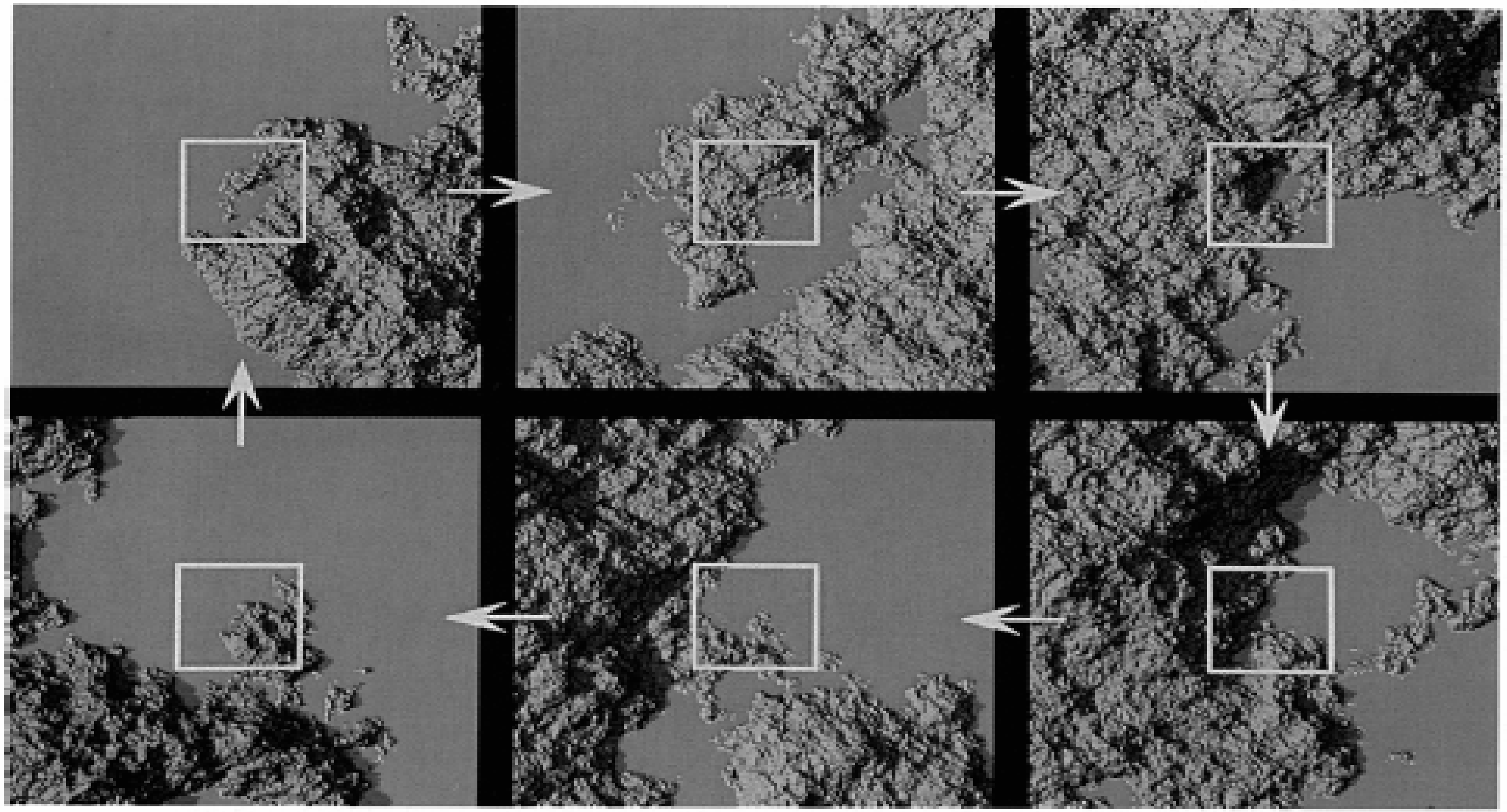
Real world fractals

A cloud, a mountain, a flower, a tree

or a coastline…

The coastline of Britain





Fractal Coastline (6 magnifications)

Euclid dimension

- In Euclid geometry, dimensions of objects are defined by integer numbers.
- 0 - A point
- 1 - A curve or line
- 2 - Triangles, circles or surfaces
- 3 - Spheres, cubes and other solids

- For a square we have N^2 self-similar pieces for the magnification factor of N

dimension=log(number of self-similar pieces)
/log(magnification factor)
=log(N^2)/logN=2

For a cube we have N^3 self-similar pieces

dimension=log(number of self-similar pieces)
/log(magnification factor)
=log(N^3)/logN=3

Sierpinski triangle consists of three self-similar pieces with magnification factor 2 each

dimension=log3/log2=1.58

Example: Cantor Set

- The oldest, simplest, most famous fractal

1 We begin with the closed interval [0,1].

2 Now we remove the open interval (1/3,2/3); leaving two closed intervals behind.

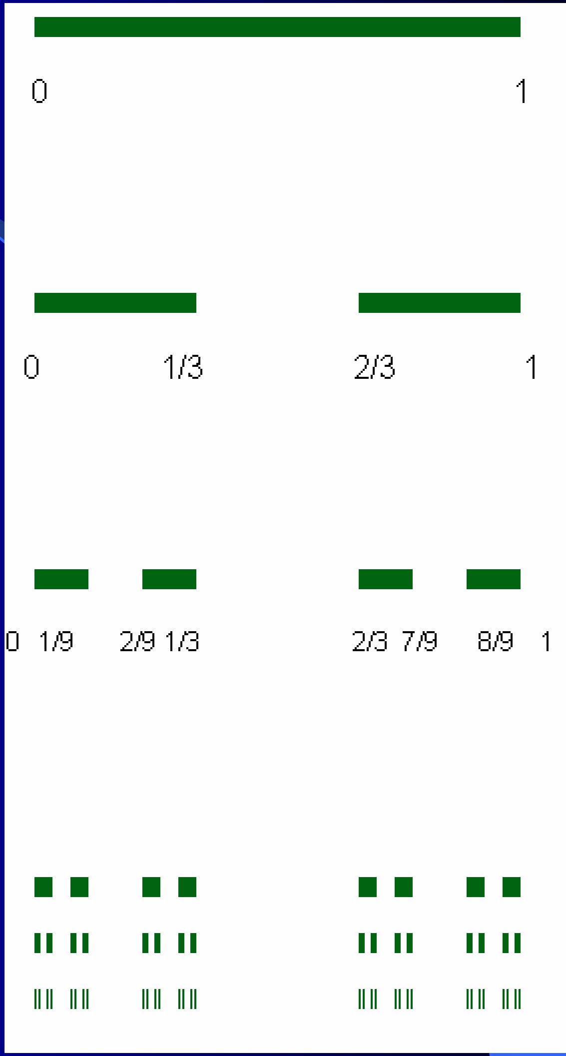
3 We repeat the procedure, removing the "open middle third" of each of these intervals

4 And continue infinitely.

- Fractal dimension:

  $D = \log 2 / \log 3 = 0.63\ldots$

- Uncountable points, zero length



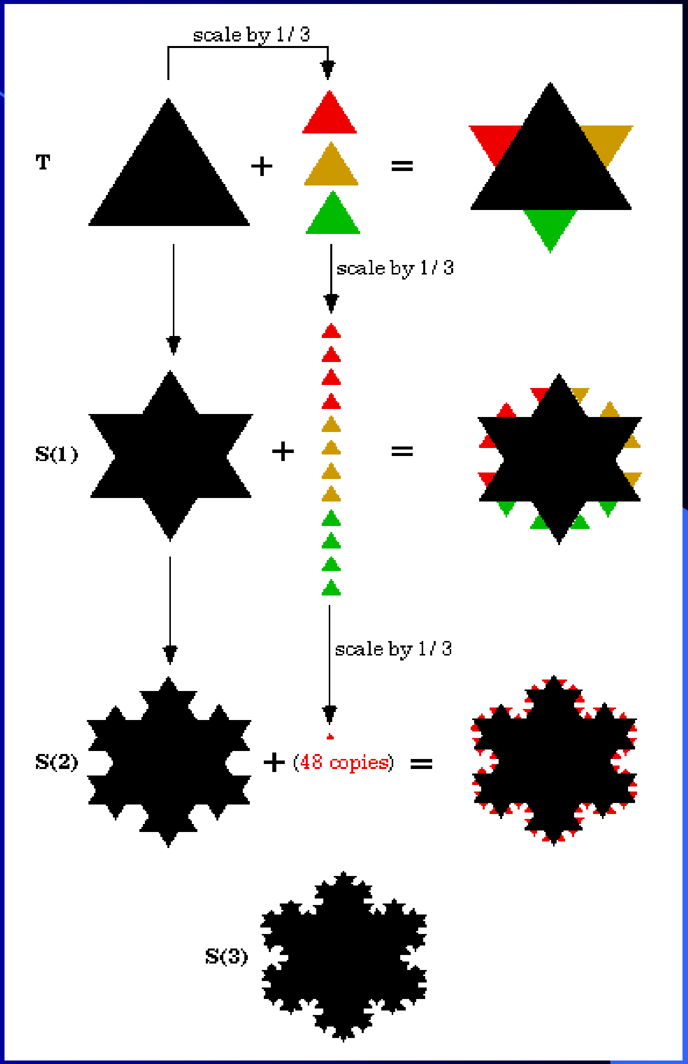
Helge von Koch Snowflake

- Step One.
  Start with a large equilateral triangle.
- Step Two.
  Make a Star.

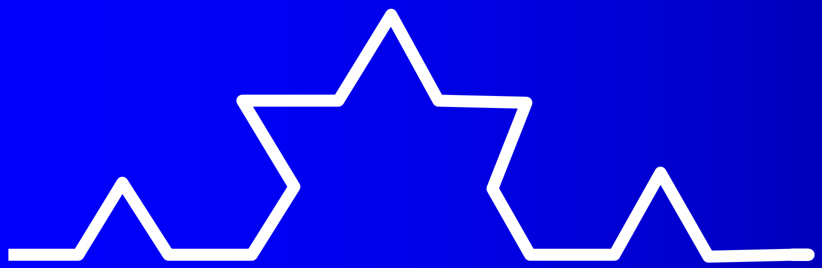
1. Divide one side of the triangle into three parts and remove the middle section.
2. Replace it with two lines the same length as the section you removed.
3. Do this to all three sides of the triangle.

- Repeat this process infinitely.

- The snowflake has a finite area bounded by a perimeter of infinite length!



Scaling/dimension of the von Koch curve

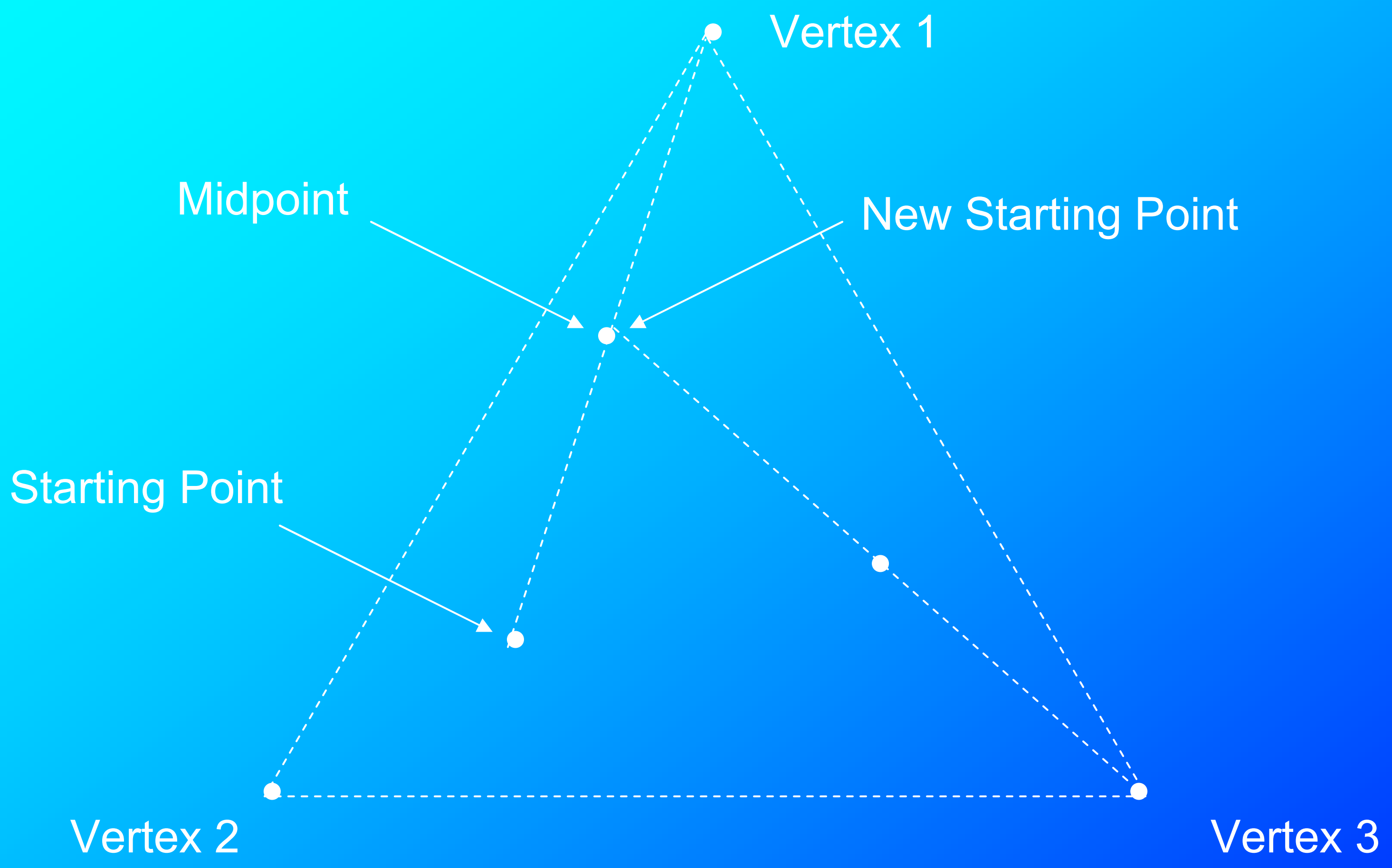


- Scale by 3 – need four self-similar pieces
- D=log4/log3=1.26

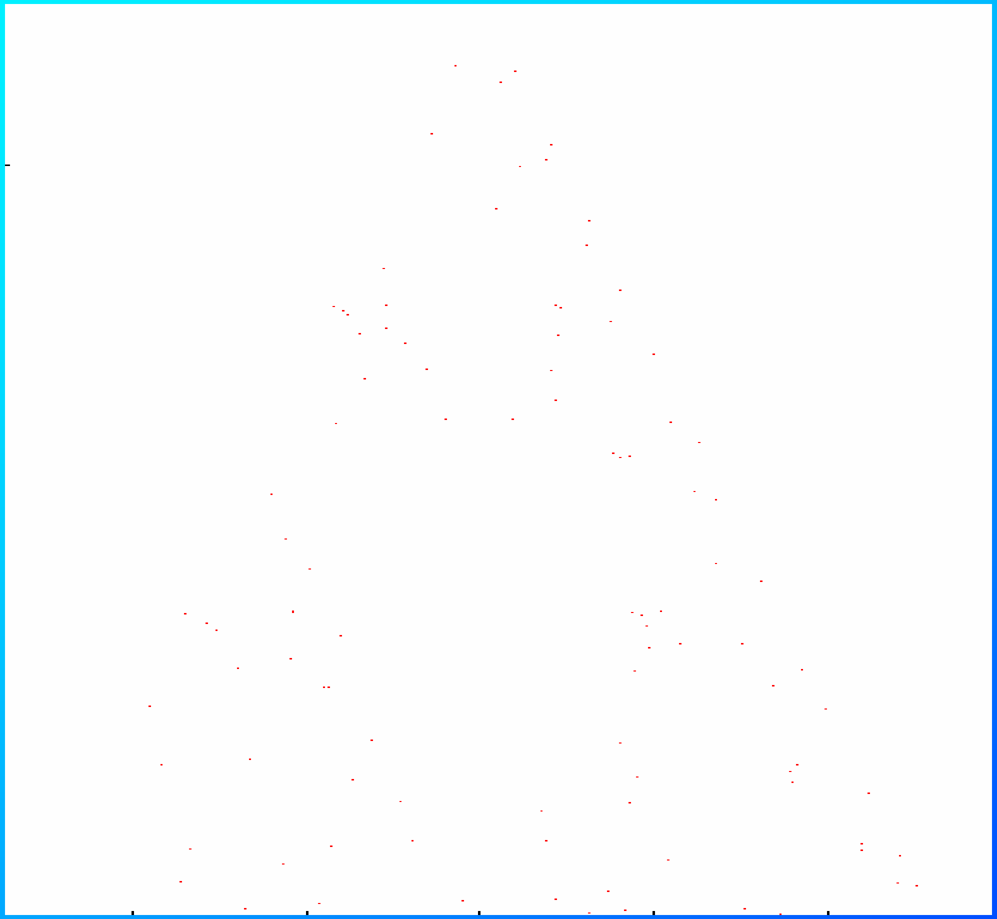
Sierpiński Fractals

- Named for Polish mathematician Waclaw Sierpinski
- Involve basic geometric polygons

Sierpinski Chaos Game

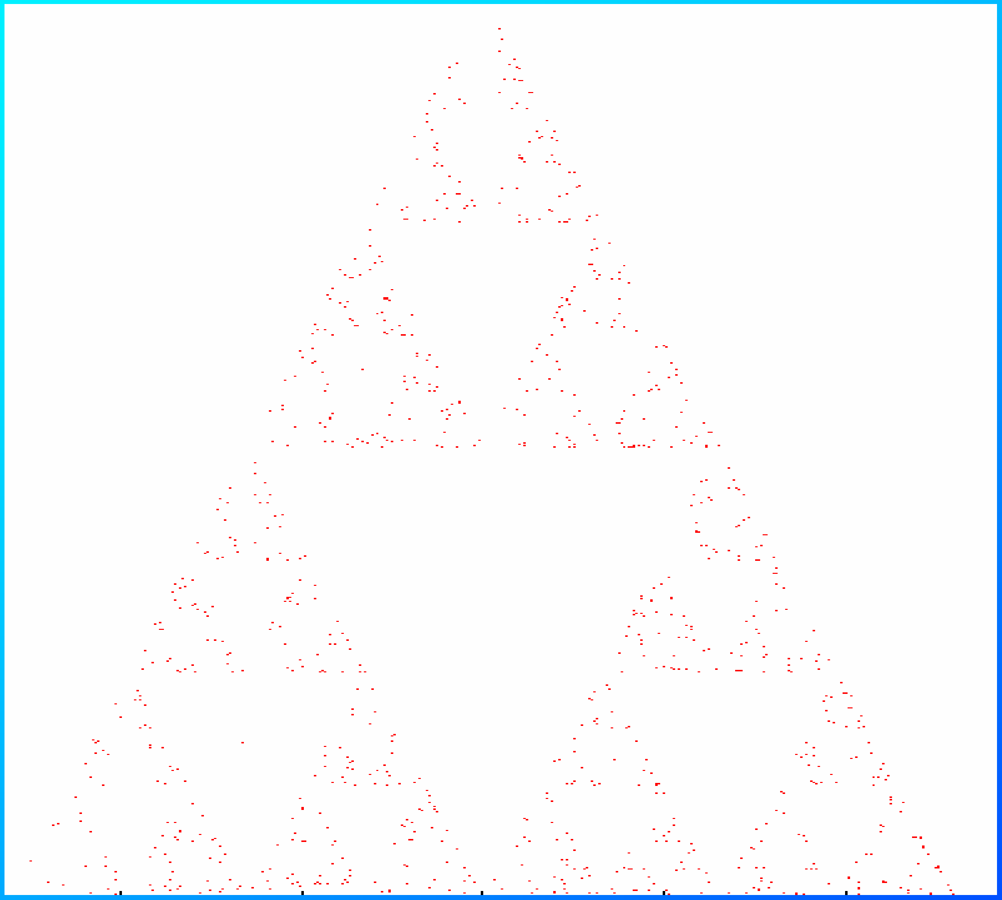


Sierpinski Chaos Game



100 pts

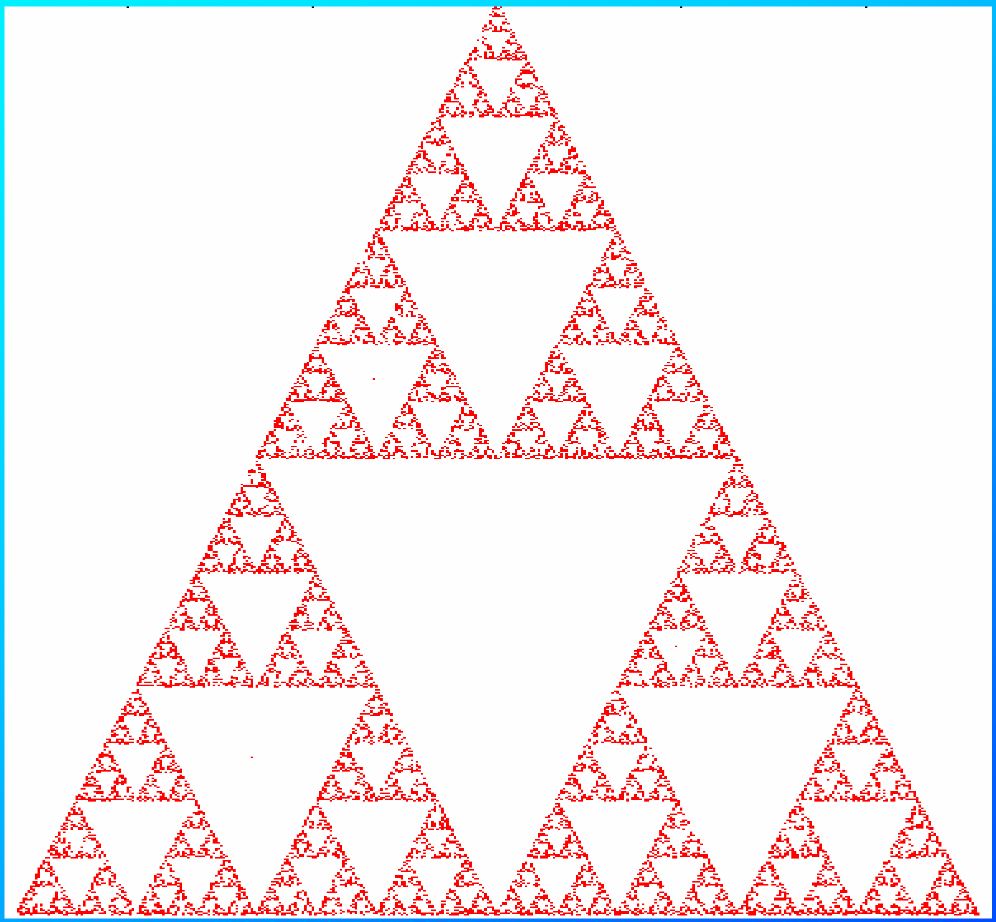
Sierpinski Chaos Game



- 1000 pts

Sierpinski Chaos Game

Fractal dimension = 1.8175…



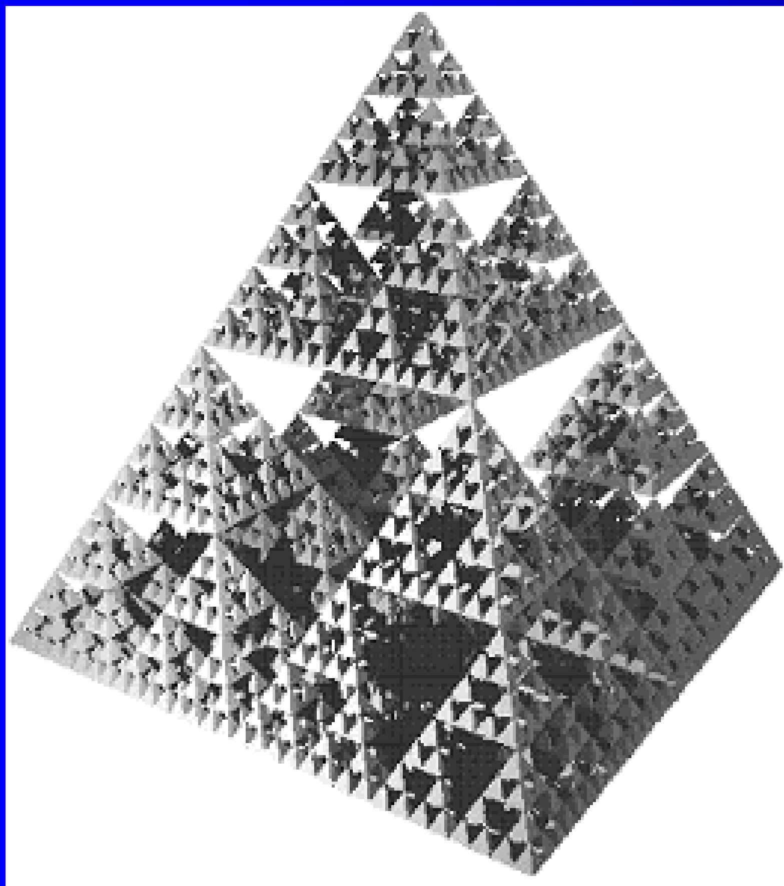
- 20000 pts

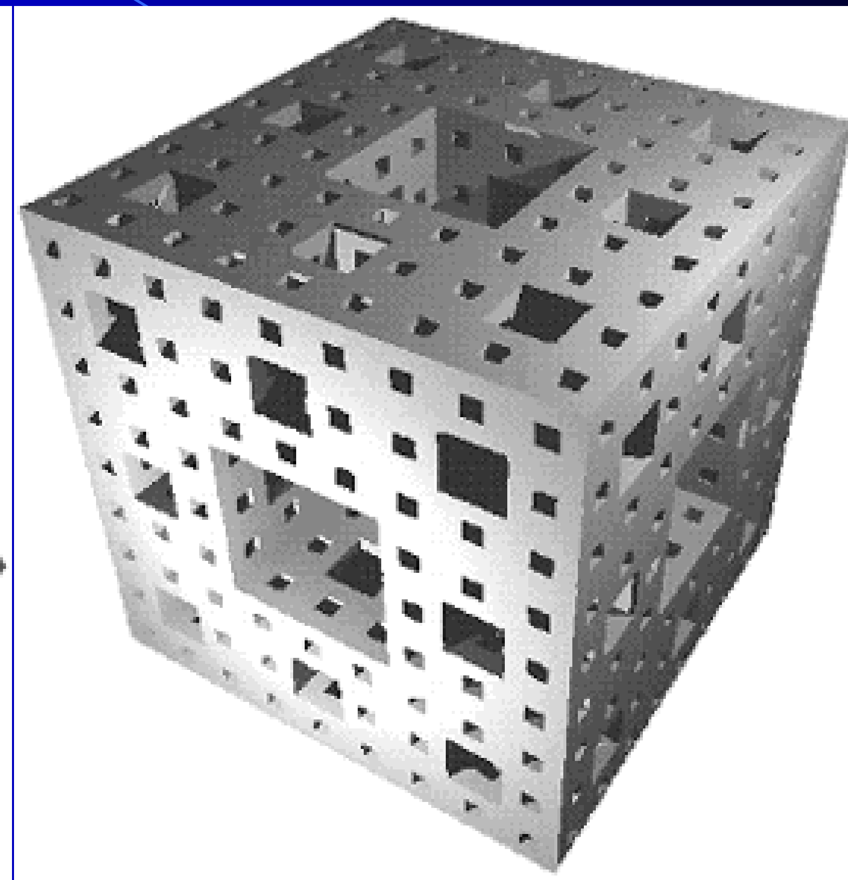
- Most important properties for applications
- Fractal structures embedded in 2D have

  finite area but infinite perimeter
- Fractal structures embedded in 3D have

  finite volume but infinite surface

In 3-D

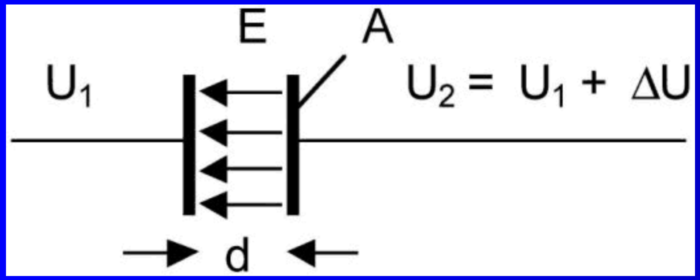




- **These "broken curves" have been used to explain naturally-occurring phenomenon such as lightning, galactic clusters and clouds. Many computer-image compression schemes are based on fractals. Until recently, however, there have been few hardware applications of fractal geometry.**

Physical relations for capacitors

Both electrodes have a surface A (in m^2) separated by distance d (in m). The applied voltage ΔU (in Volt) creates an electric field $E = \Delta U/d$ storing the electrical energy. Capacitance C in Farad (F) and stored energy J in Ws is:



$$C = \varepsilon_0 \cdot \varepsilon_r \frac{A}{d} \qquad J = \tfrac{1}{2} C \cdot \Delta U^2$$

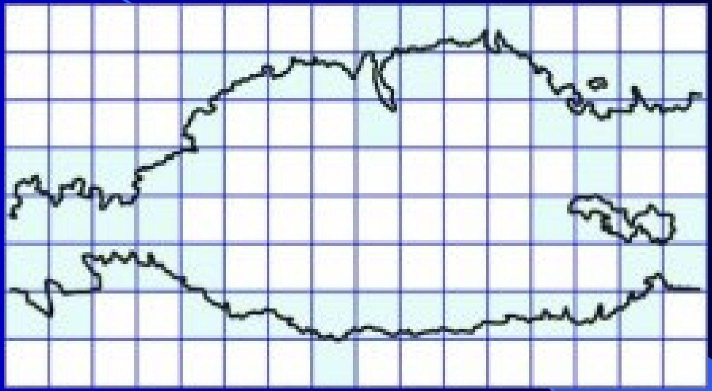
where ε_r (e.g. 1 for vacuum or 81 for water) is the relative dielectric constant which depends on the material placed between the two electrodes and $\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m is a fundamental constant.

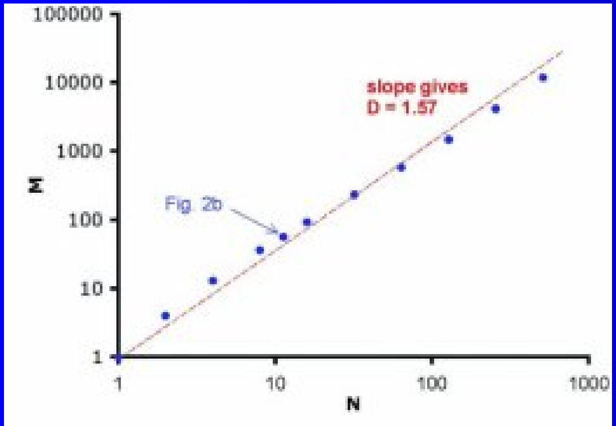
Capacitance in Farad	1000	$1\cdot10^{-3}$	$1\cdot10^{-6}$	$1\cdot10^{-9}$	$1\cdot10^{-12}$
Example	 supercapacitor with 1500 F, max. 2.5 V (positive electrode left)	 electrolyte capacitor with 1000 mF, max. 25 V (positive electrode left)	 electrolyte capacitor with 10 mF, max. 35 V (bent wire is positive electrode)	 rolled capacitor with 51 nF, max. 63 V	 plate capacitors with 50 pF. Left: an element from an old vacuum-tube radio in the form of two plates rolled to a cylinder, max. 450 V. Right: modern ceramic element, max. 100 V)
Energy Stored	Watt hours (Wh)	several Ws (Ws)	milli-Ws = 10^{-3} Ws (mWs)	milli-Ws = 10^{-3} Ws (mWs)	micro-Ws = 10^{-6} Ws (mWs)
Applications	Novel applications in power electronics: e.g. in cars, for replacing batteries in consumer electronics	Power supply units	Low frequency technology: general electronics, e.g. audio amplifiers	Low frequency technology: general electronics, e.g. audio amplifiers	High frequency technology: e.g. radio, TV, PC

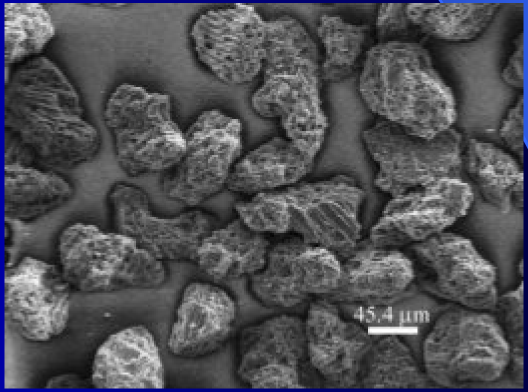
How to create capacitors with larger C?

- Create capacitors with very large areas A – technologies to create fractal-type surfaces
- Use designs taking advantage of lateral capacitance in integrated circuits

Electrochemically modified glassy carbon is a promising material to be used in electrochemical capacitors. Oxidation of the surface of a glassy carbon electrode results in a porous layer with very large capacitance and fairly low internal resistance when using an aqueous electrolyte.

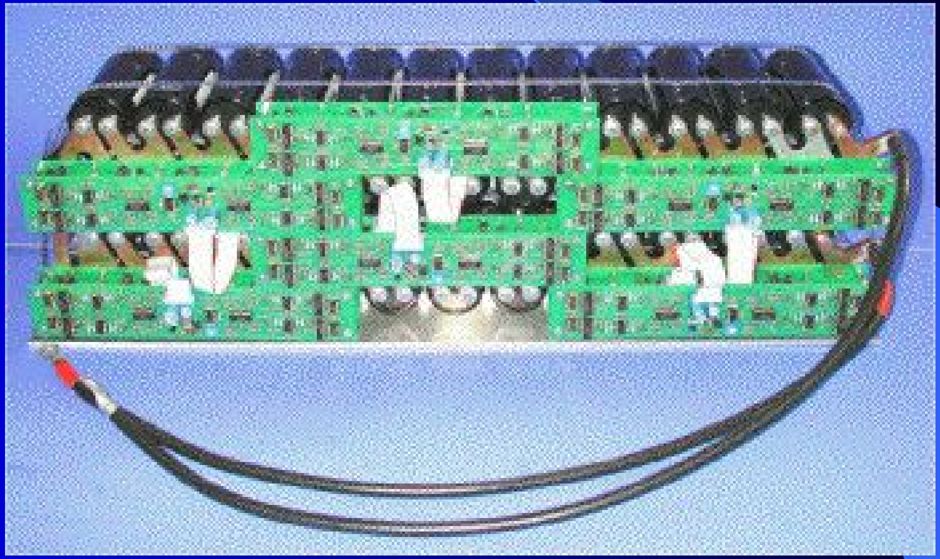






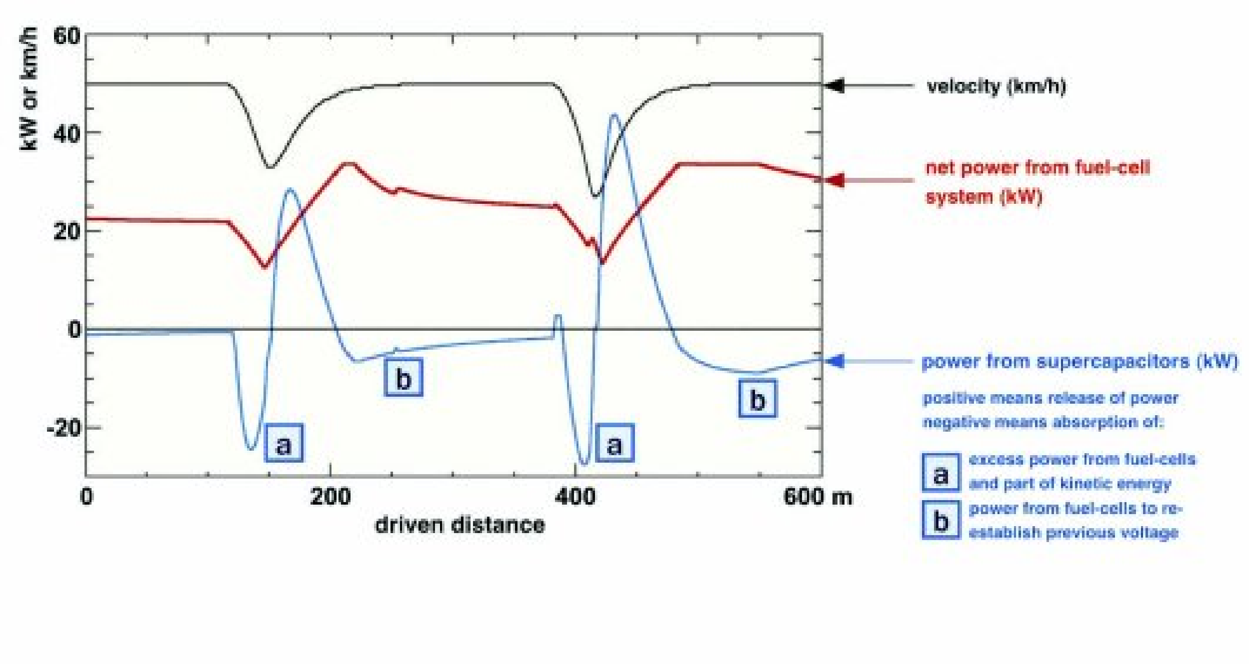
- Paul Scherrer Institute in Villigen, Switzerland - Rüdiger Kötz and his group have developed an electrode in collaboration with the Swiss company *Montena* (*Maxwell*).

- a) Micrograph of a cross section through a supercapacitor electrode.The white stripe is a part of the 30 µm thick metallic carrier-foil (total foil is 0.1 m wide, 2 m long). On both sides carbon particles provide a complex fractal surface responsible for the high capacity.The space taken by the green resin used to fix the delicate carbon structure before cutting and to provide a good contrast for imaging is normally filled with the electrolyte (an organic solvent containing salt ions).
  b) Borderline of the cross section through the electrode surface in (a) to be analyzed by the box-counting procedure, illustrated for a tiling with 128 squares:M = 56 squares (filled with light blue colour) are necessary to cover the borderline.Their side lengths are N = 11.3 (square root of 128) times smaller than the length scale of the whole picture.
  c) The box-counting procedure is repeated with a computer program for different N.The average fractal dimension of the borderline is the gradient of the straight line approximating the measured points in this Log(M) over Log(N) plot, giving D 1.6.This same dimension was measured in the lengthinterval covering nearly 3 decades between 0.6 mm (length of micrograph in Figs 2a, b) and about 1 µm (fine structure in Fig. 2d).
  d) Carbon particles as seen with an electron microscope show roughness also in the 1 µm scale. It is assumed that the above indicated fractal dimension D holds over the entire range of 8 decades between the macroscopic scale (i.e. the geometric size of the order of 0.1 m) and the microscopic scale (i.e. the micropores in the order of 1 nm = $1{\cdot}10^{-9}$ m).The electrode surface is therefore multiplied by $10^{8*0.6}$ or about 60’000 when compared to the normal two-dimensional surface of 0.2 m^2.



- *800 F boostcap by montena SA utilizing PSI electrode.*
- *Capacitor module with 2 x 24 capacitors resulting in 60 V , 60 F with an overall internal resistance of < 20 mOhm.*

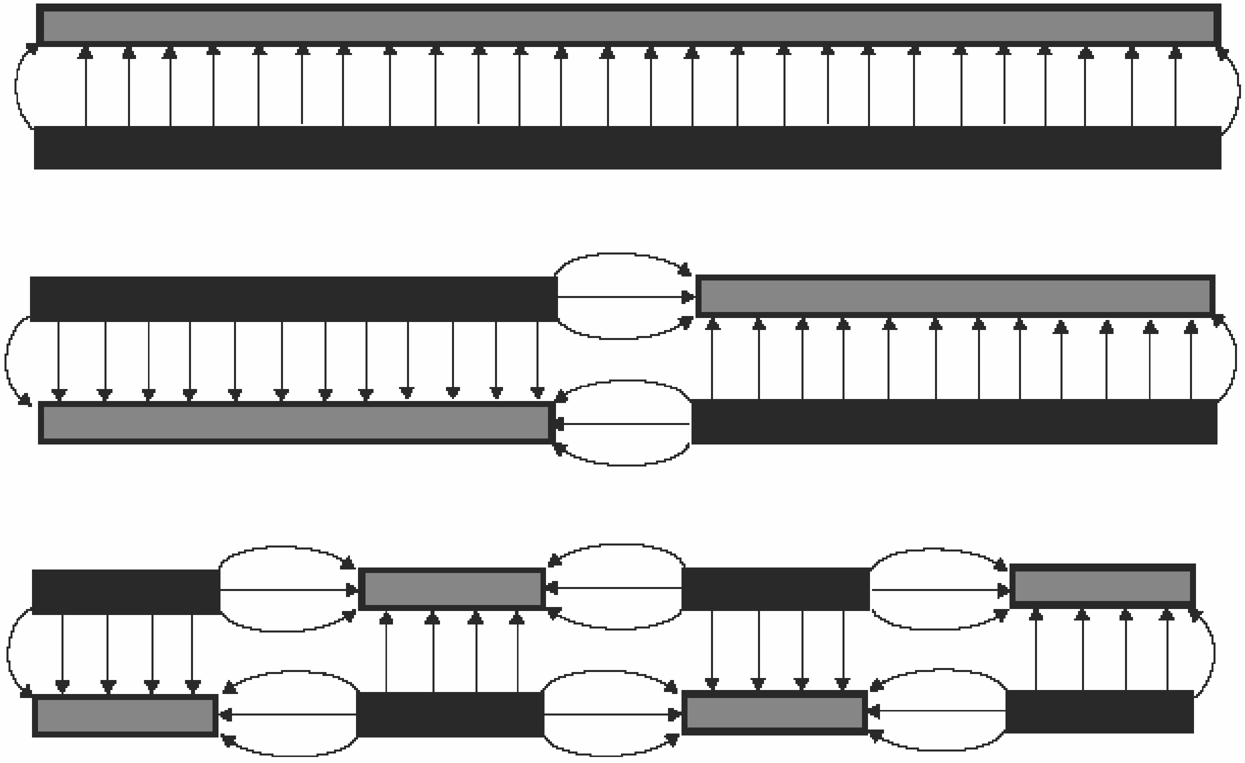
- Supercapacitor module for HY-LIGHT.
  Capacitance: 29 F
  Power: 30 - 45 kW for 20 - 15 sec ; Weight: 53 kg
- HY-LIGHT accelerates to 100km/h in 12 seconds


kW or km/h
60
40
20
0
-20
0
200
400
600 m
driven distance
velocity (km/h)
net power from fuel-cell system (kW)
power from supercapacitors (kW)
positive means release of power
negative means absorption of:
a excess power from fuel-cells and part of kinetic energy
b power from fuel-cells to re-establish previous voltage
a
b
a
b


HY.POWER

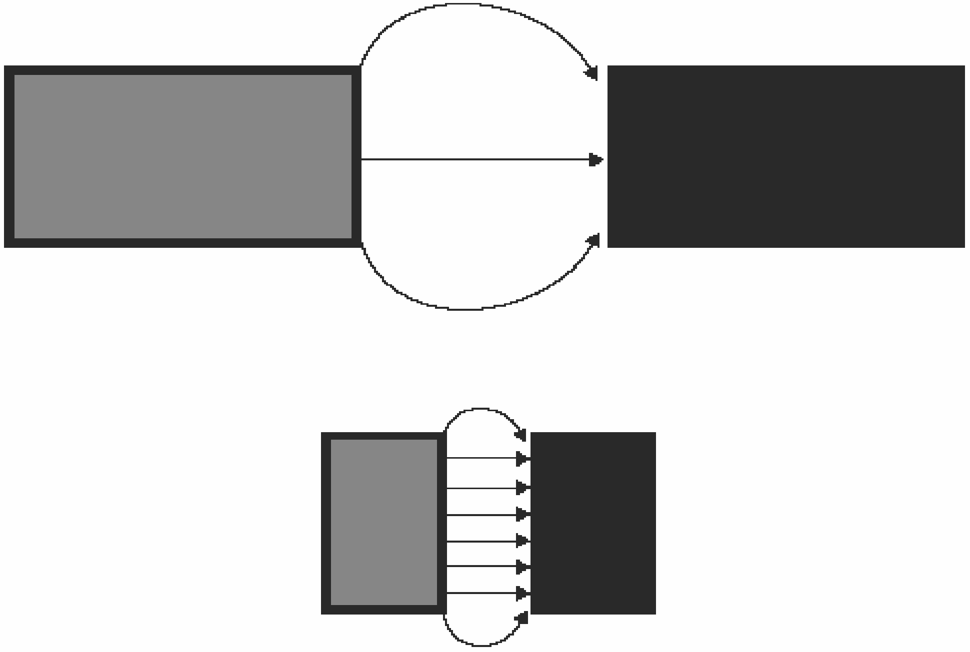
Vertical vs. Lateral Flux

- Lateral flux increases the total amount of capacitance.

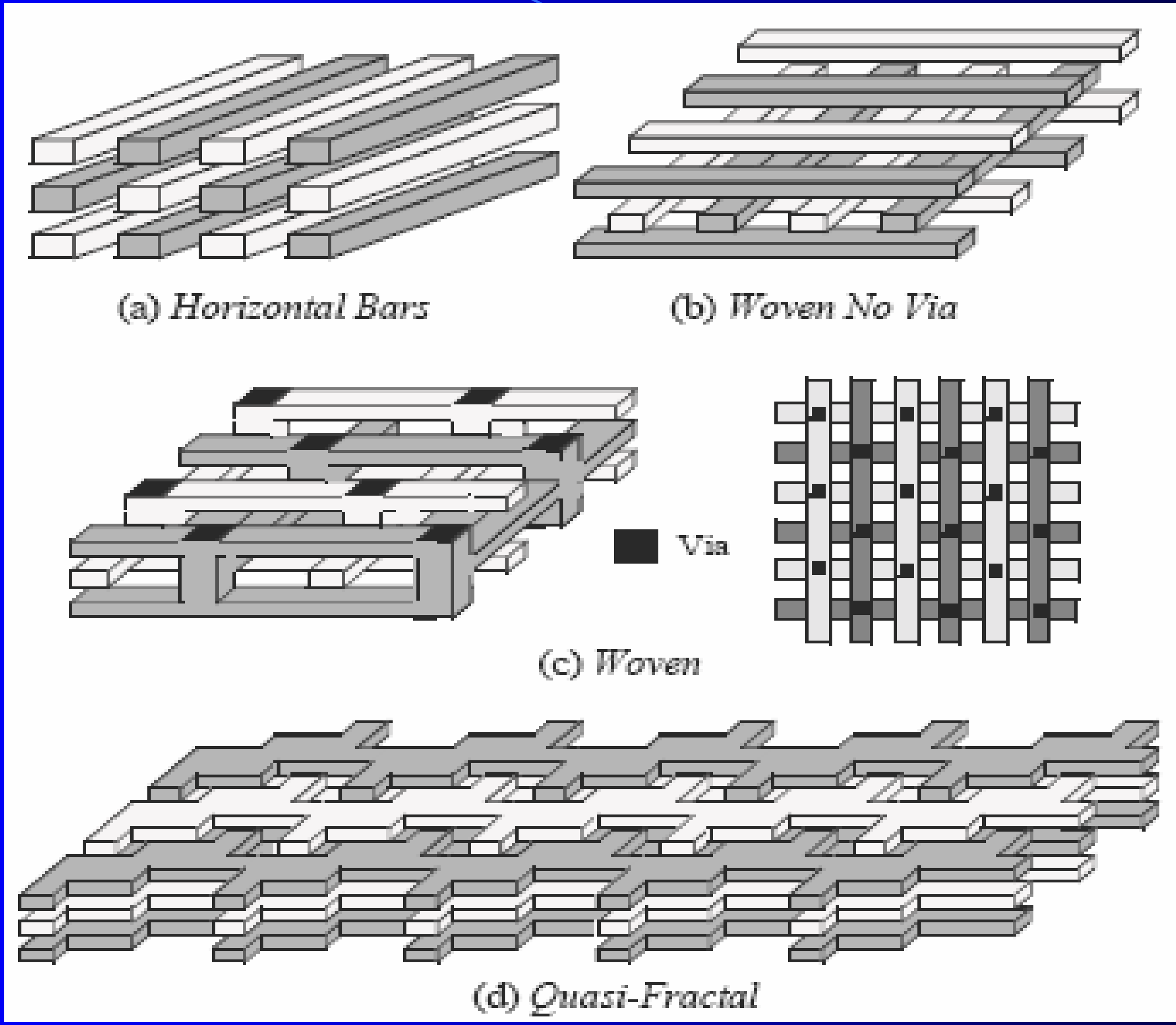


Scaling

- Unlike conventional parallel-plate structures, the capacitance per unit area increases as the process technologies scale.

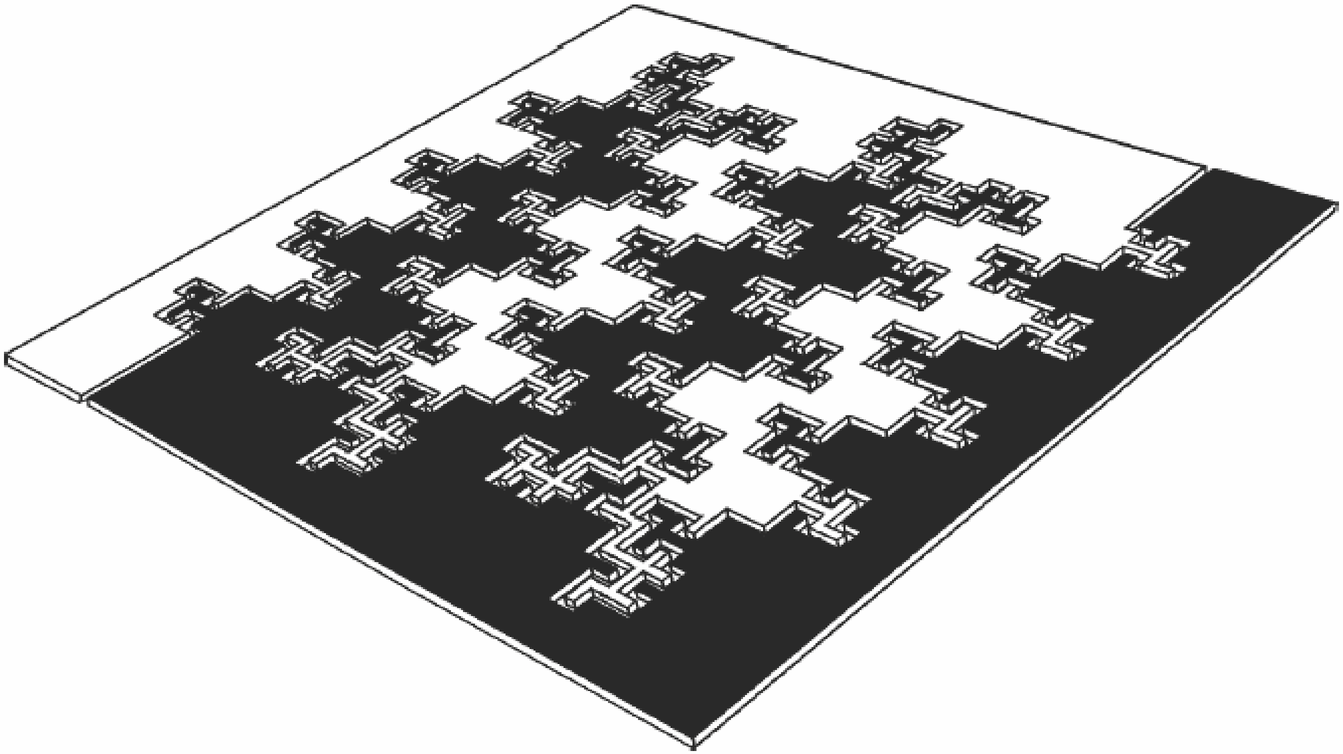


Manhattan capacitor structures



Fractal Capacitor

- Quasi fractal geometries can be utilized to increase capacitance per unit area.



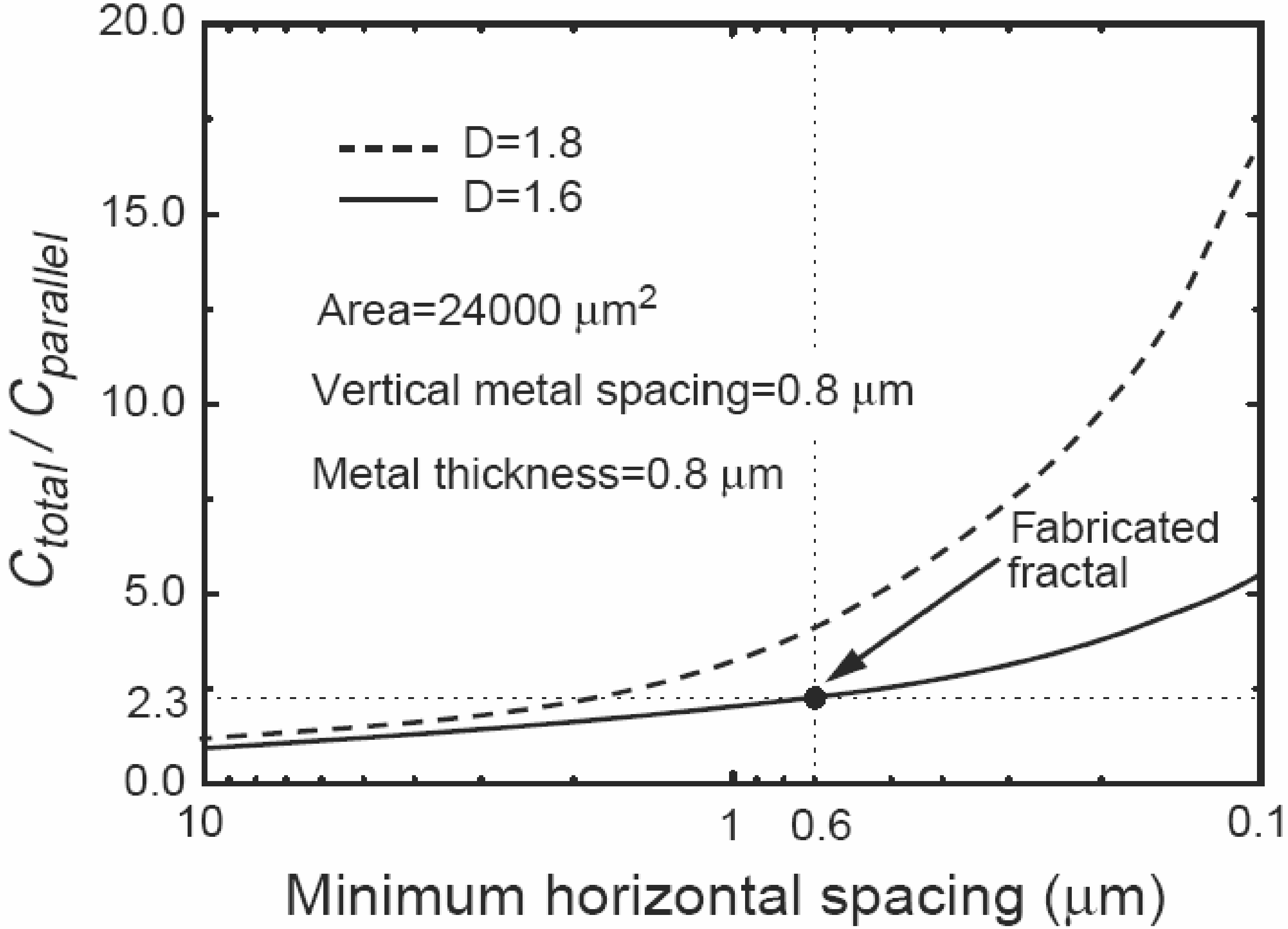
3-D representation of a fractal capacitor using a single metal layer.

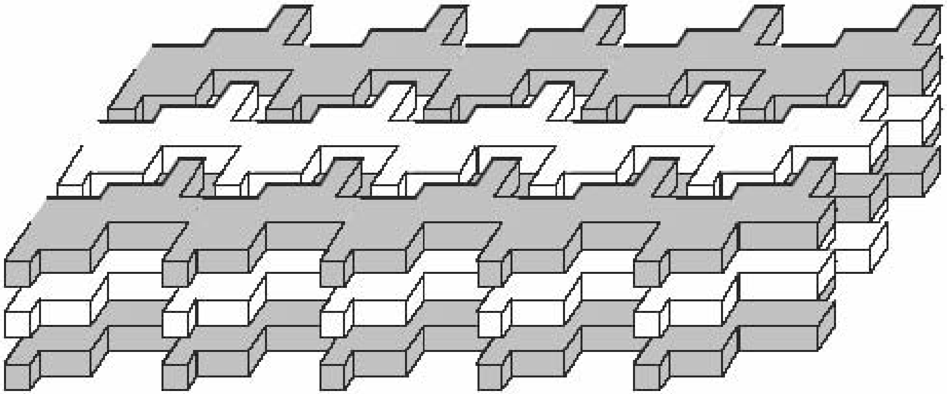
Capacitance Estimation

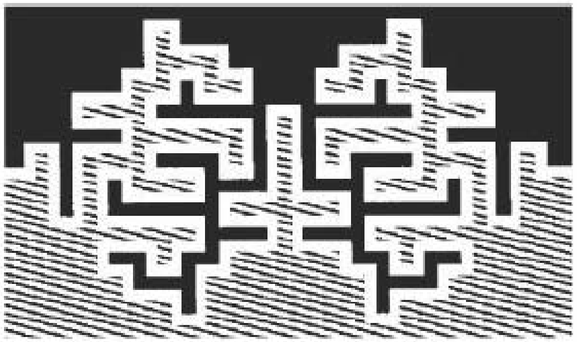
$$C_{lateral} = K \frac{(\sqrt{A})^{D}}{(w + s)^{D-1}} \times t$$

- *w*: Minimum width of the metal.
- *s*: Minimum spacing between two adjacent strips.
- *A*: Area of the fractal capacitance.
- *t*: Thickness of the metal layers.
- *K*: Proportionality factor that depends on the family of fractals being used.
- *D*: Fractal dimension.

Boost Factor *vs.* Lateral Spacing

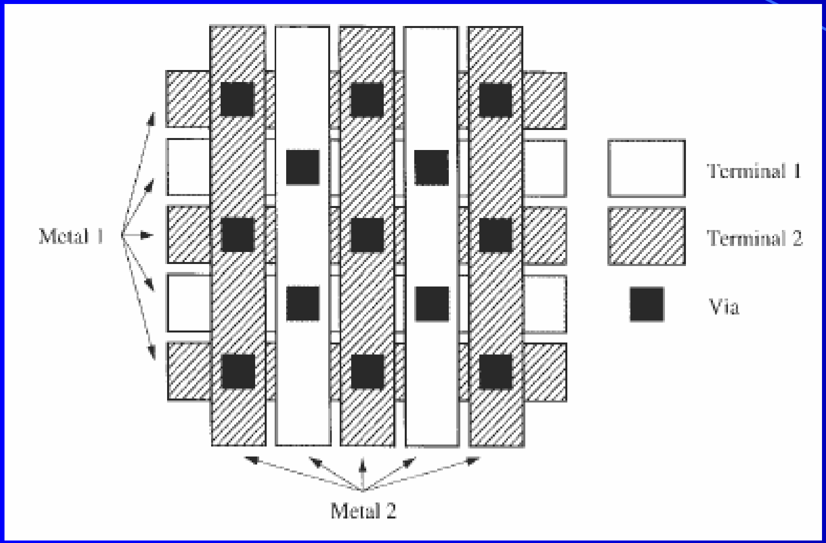


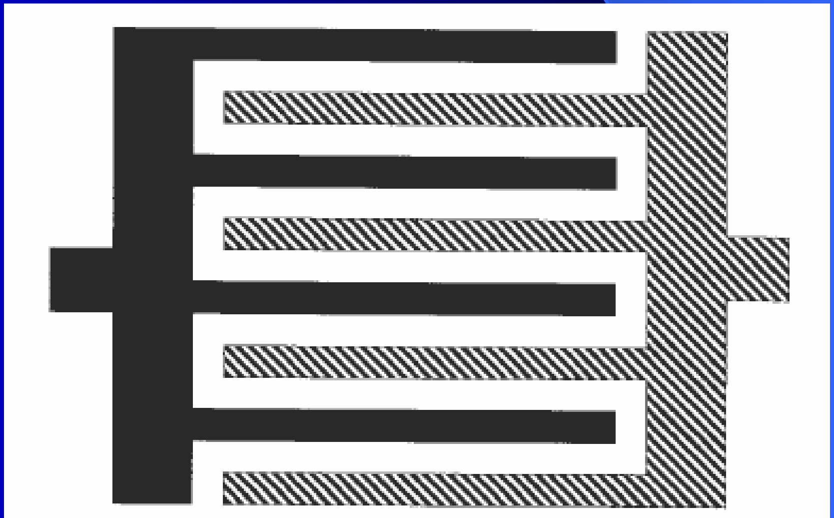




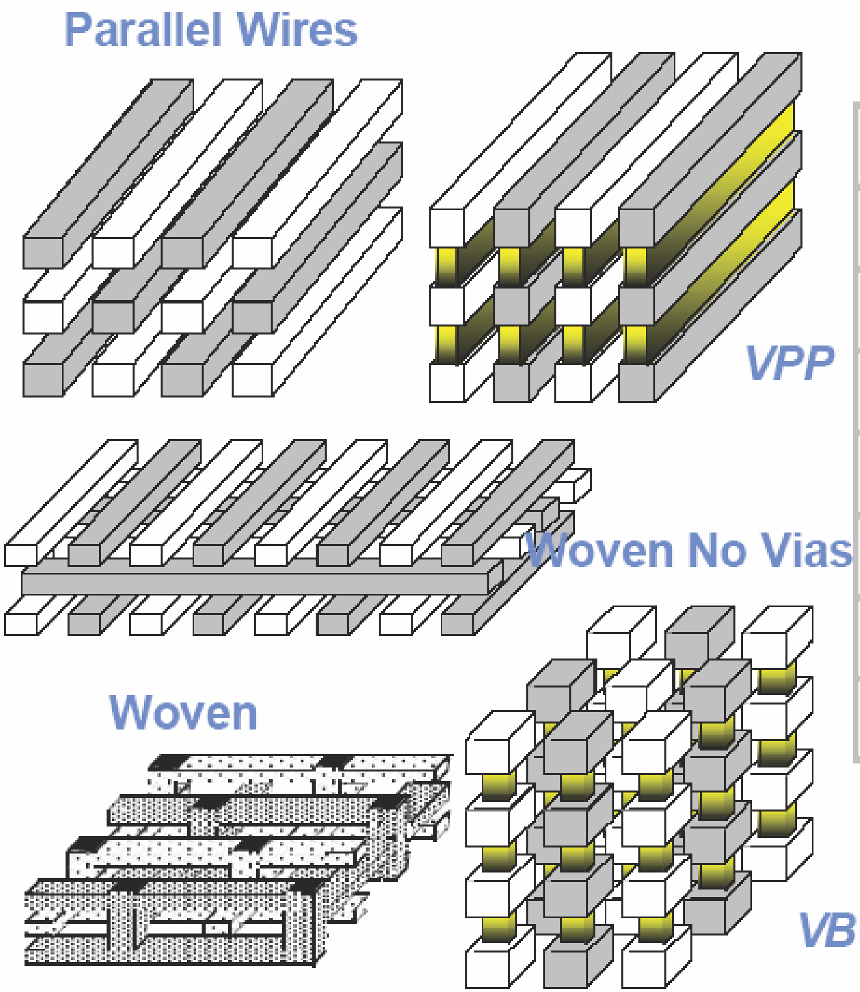
- Quasi-fractal structures maximize periphery to increase field usage,
- Have strong vertical *and* lateral components,
- Time consuming to generate and simulate,
- Look beautiful !

[Samavati, Hajimiri, Shahani, Nasserbakht, and Lee, ISSCC 1998]


Metal 1
Terminal 1
Terminal 2
Via
Metal 2



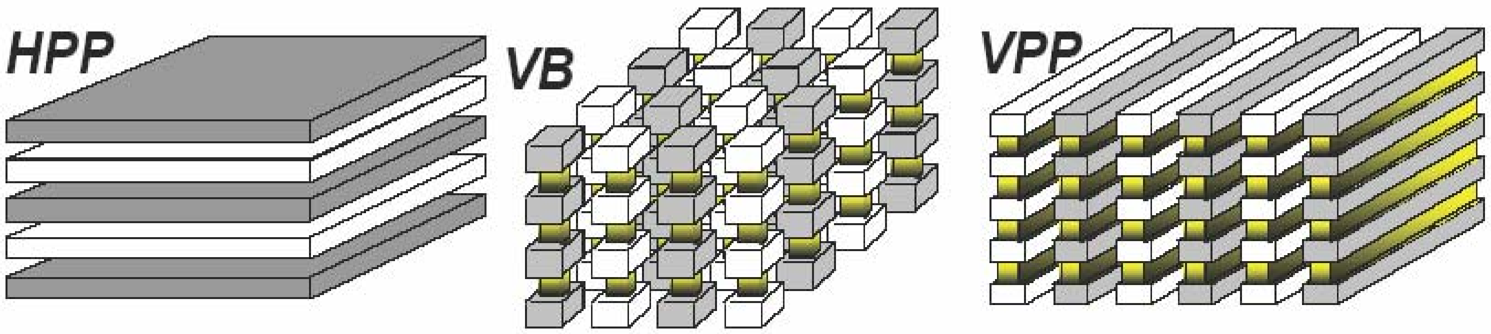
Capacitance density comparison



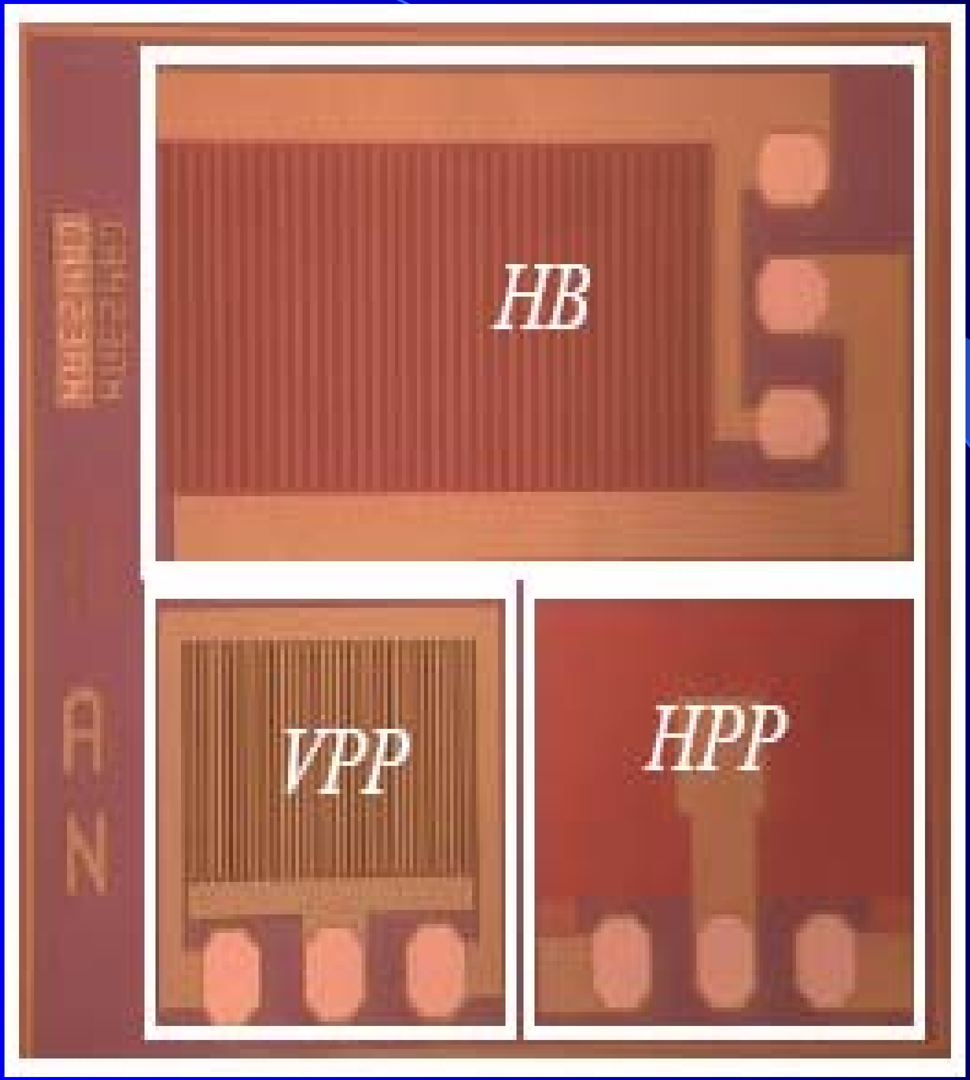
	% TL1	% TL2
Woven	37.0%	52.7%
Woven no Vias	28.3%	40.3%
Parallel Wires	28.3%	40.3%
Quasi-Fractal	17.9%	25.5%
Horizontal PP	0.8%	1.1%
Vertical PP	49.6%	70.7%
Vertical Bars	63.7%	90.8%

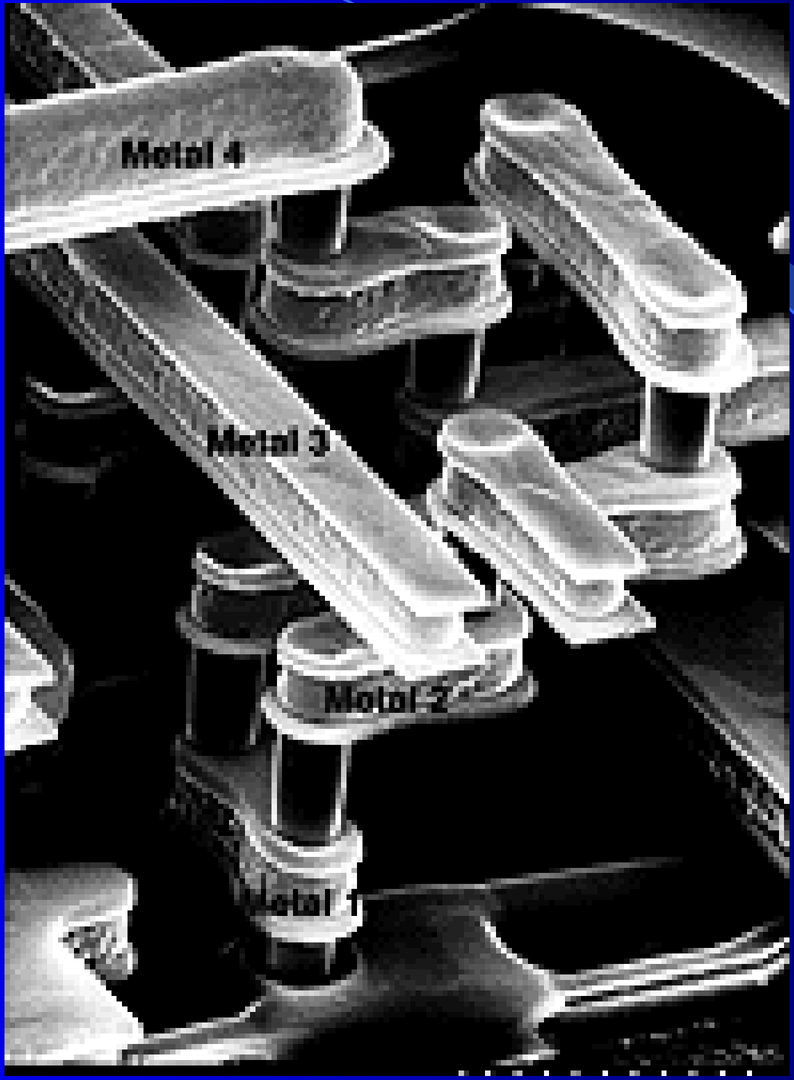
[Aparicio and Hajimiri, JSSC March 2002]

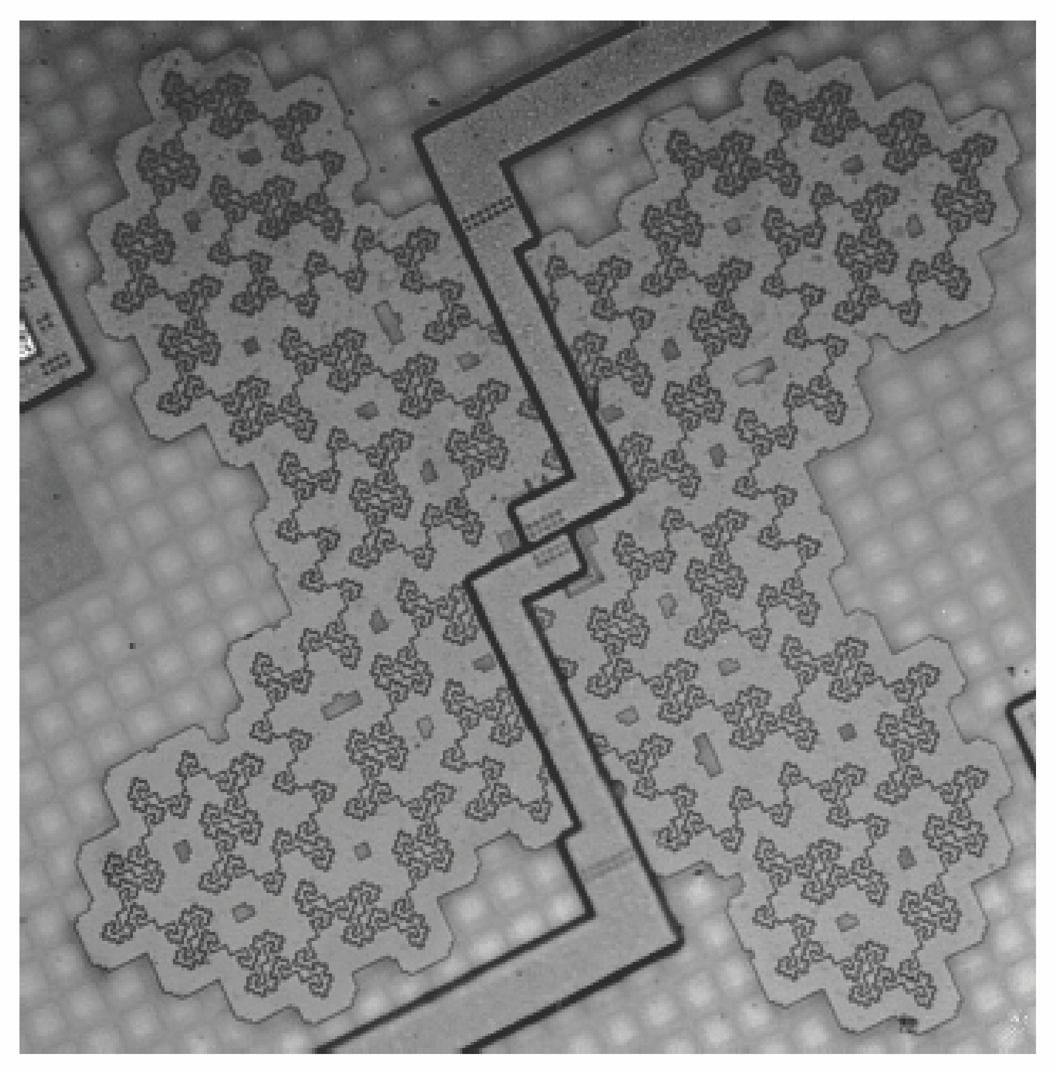
Measurement Summary



	HPP	VB	VPP	MIM 0.18μ
Average Cap. [pF]	1.095	1.076	1.013	1.057
Cap. Density [aF/μm^2]	203.6	1281.3	1512.2	1100
Cap. Enhancement	1	6.29	7.43	5.40
f_{res} [GHz]	21	37.1	40 <	11
Q (Measured) @1GHz	63.8	48.7	83.2	95


HB
VPP
HPP

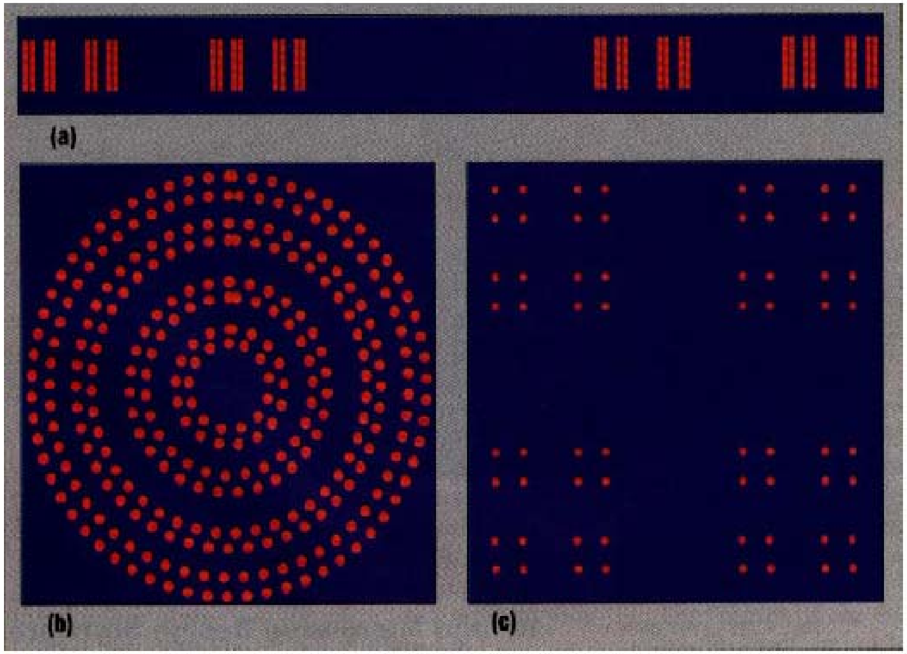

Metal 4
Metal 3
Metal 2



Open problems

- Theoretical issue: How to calculate capacitance in a „finite” fractal structure?
- Technological issues: Improve materials, find better structures

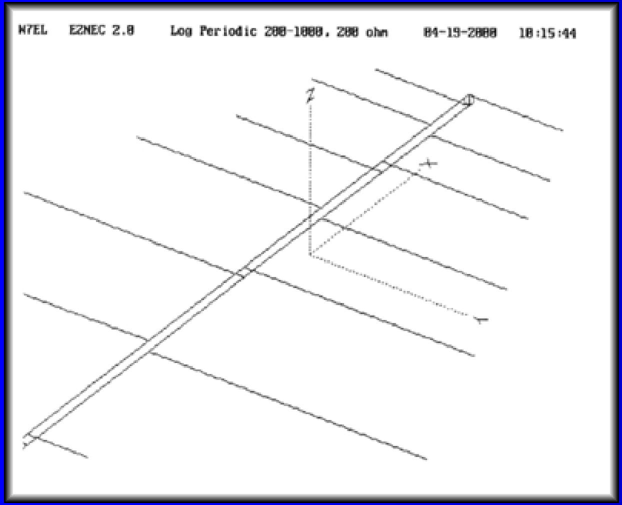
Fractal antenna arrays

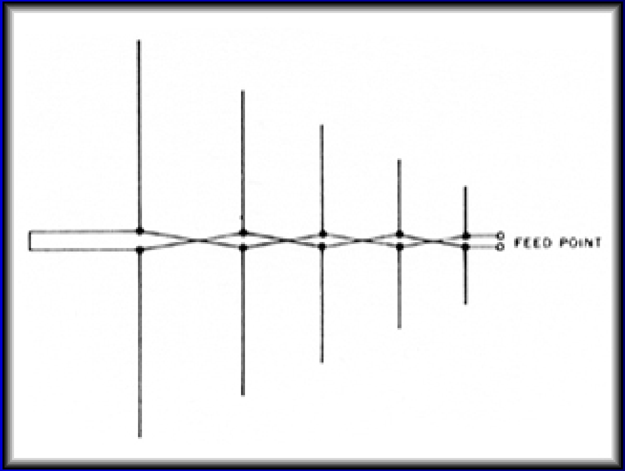


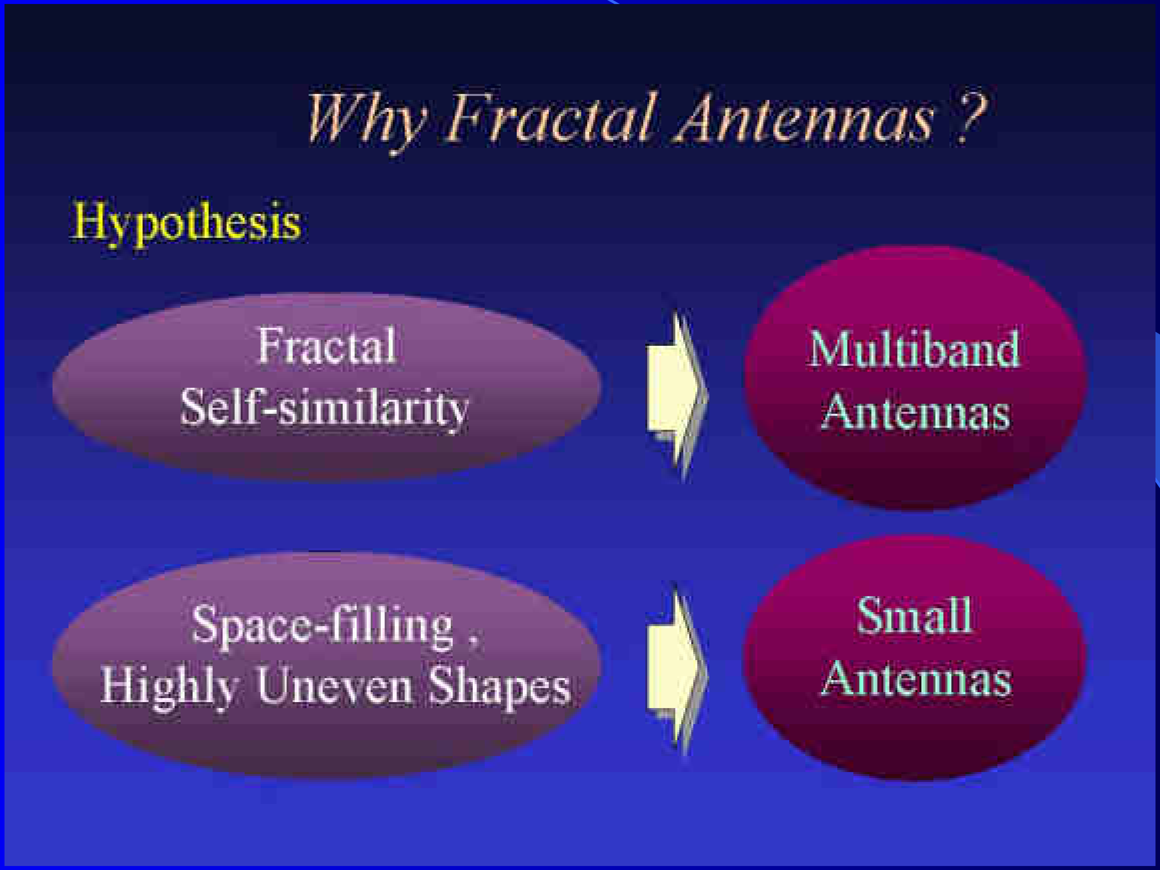
(a) Cantor linear array (b) Cantor ring array (c) Sierpinski carpet planar array

fractal antenna is an antenna that uses a self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic signals within a given total surface area. For this reason, fractal antennas are very compact, are multiband or wideband, and have useful applications in cellular telephone and microwave communications. Fractal antenna response differs markedly from traditional antenna designs, in that it is capable of operating optimally at many different frequencies simultaneously. Normally standard antennae have to be "cut" for the frequency for which they are to be used—and thus the standard antennae only optimally work at that frequency. This makes the fractal antenna an excellent design for wideband applications.

- The first fractal antennas were arrays, and not recognized initially as having self similarity as their attribute. Log-periodic antennas are arrays, around since the 1950's (invented by Isbell and DuHamel), that are such fractal antennas. They are a common form used in TV antennas, and are arrow-head in shape. Antenna elements made from self similar shapes were first done by Nathan Cohen, a professor at Boston University, in 1988. Most allusions to fractal antennas make reference to these 'fractal element antennas'.


W7EL EZNEC 2.0 Log Periodic 200-1000, 200 ohm 04-19-2000 10:15:44
Z
X
Y


FEED POINT

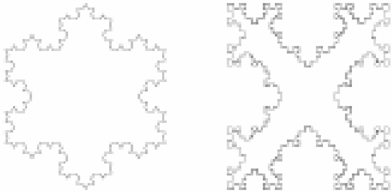

Why Fractal Antennas ?
Hypothesis
Fractal
Self-similarity
Multiband
Antennas
Space-filling ,
Highly Uneven Shapes
Small
Antennas

Which Fractals and Why?

Loops

Minimize Size

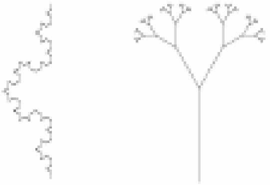
Increase Input Impedance



Dipoles

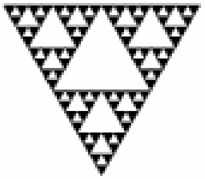
Minimize Heights

Increase Input Impedance



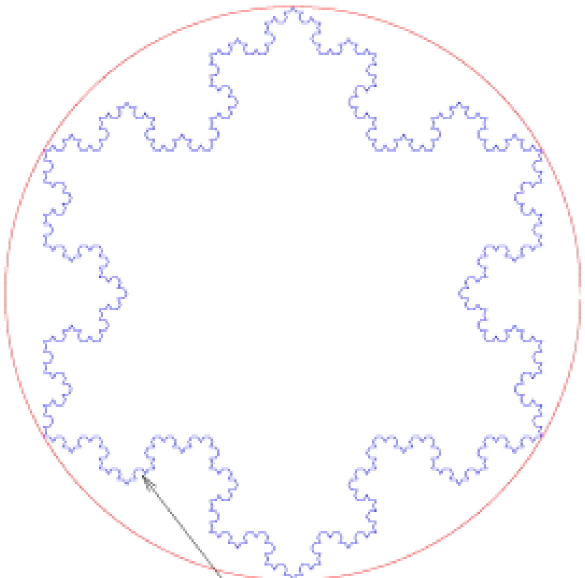
Dipoles

Multiband

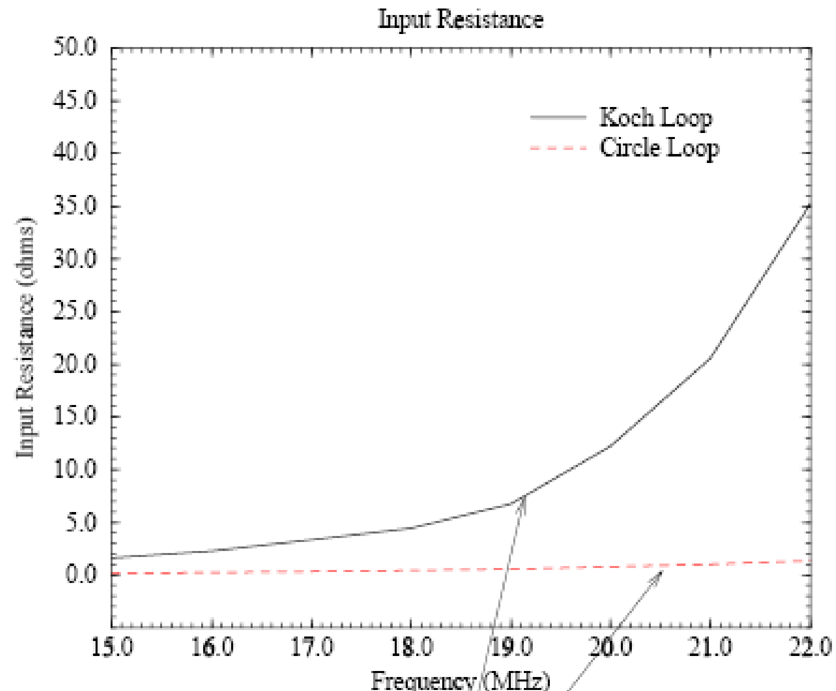


Small Fractal Loop Antennas

Main Benefit: Increased Input Impedance



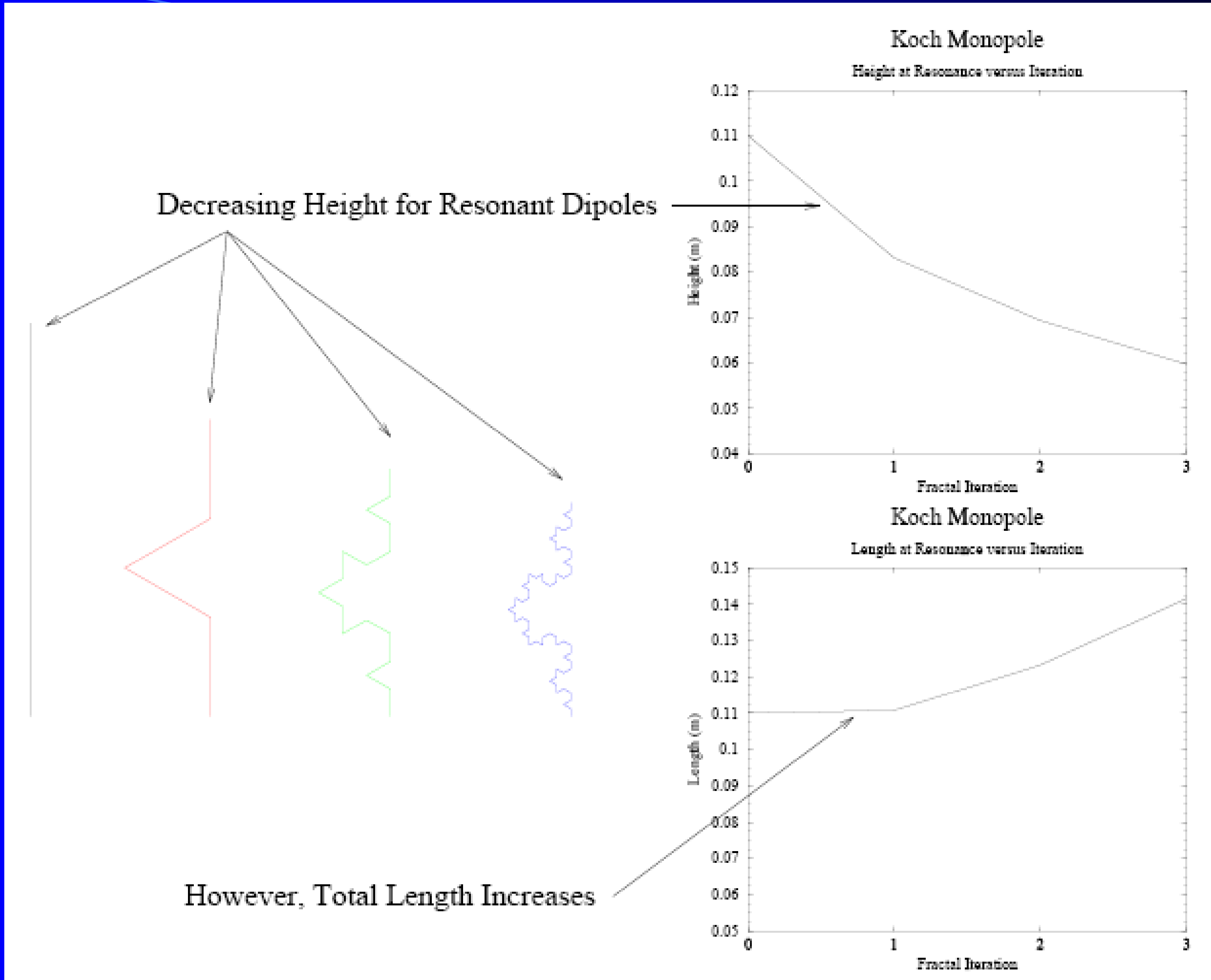
Koch Loop vs. Circular Loop



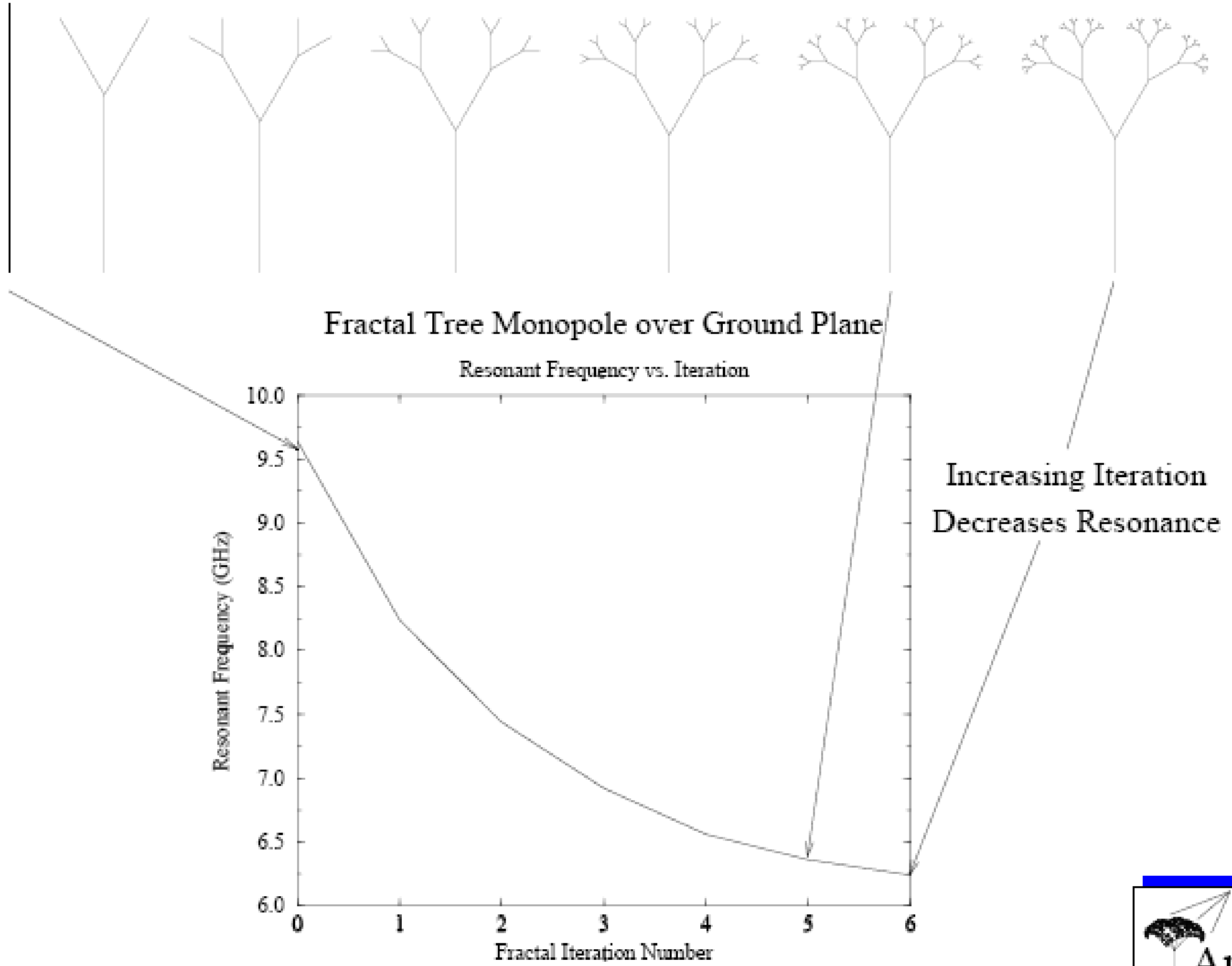
Both loops take up the same volume

But, the input impedance of the fractal loop is higher

Fractal Antennas

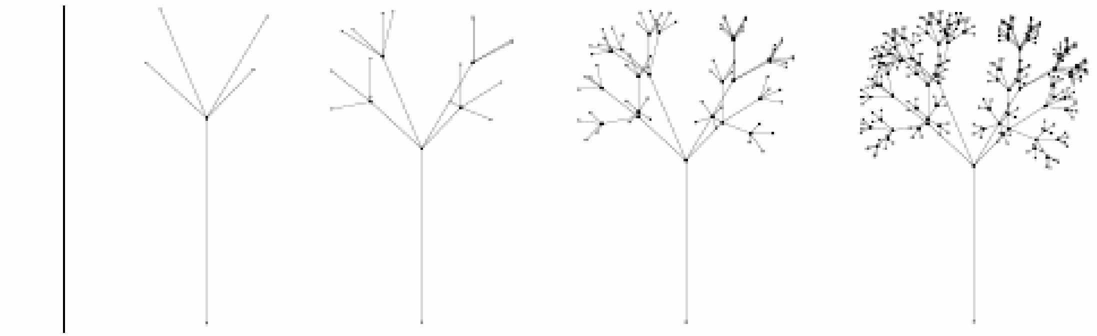

Decreasing Height for Resonant Dipoles
However, Total Length Increases
Koch Monopole
Height at Resonance versus Iteration
Height (m)
Fractal Iteration
Koch Monopole
Length at Resonance versus Iteration
Length (m)
Fractal Iteration

Main Benefit: Decreased Resonant Frequency



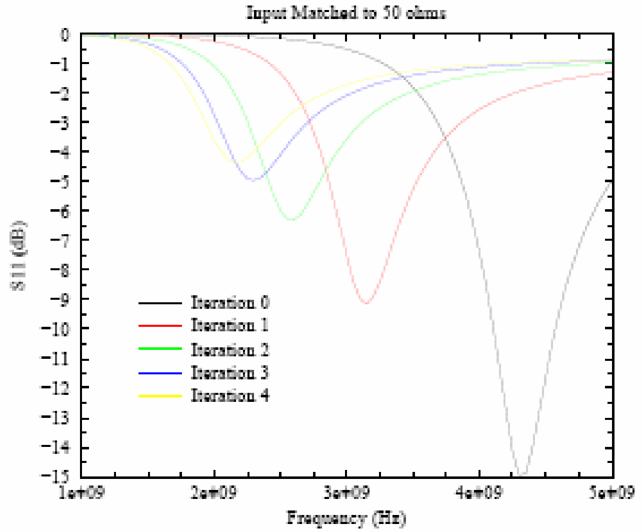
Fractal Antennas

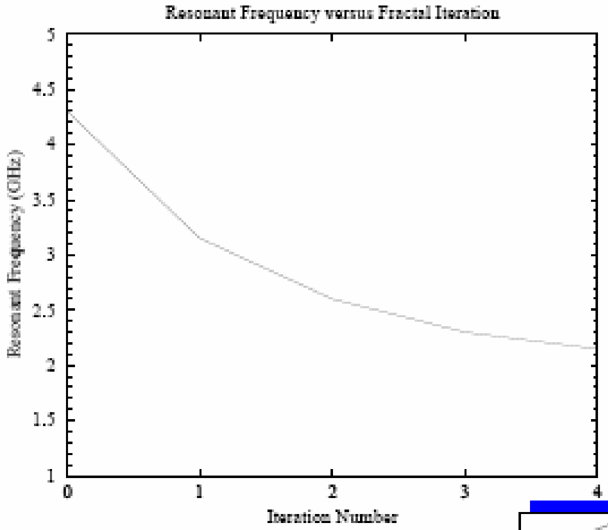
Main Benefit: Decreased Resonant Frequency



Iteration 0 Iteration 1 Iteration 2 Iteration 3 Iteration 4

3D Fractal Tree 3D Fractal Tree





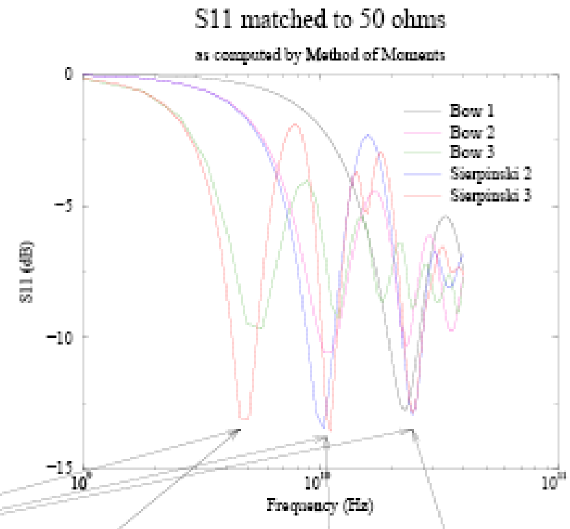
Fractal Antennas

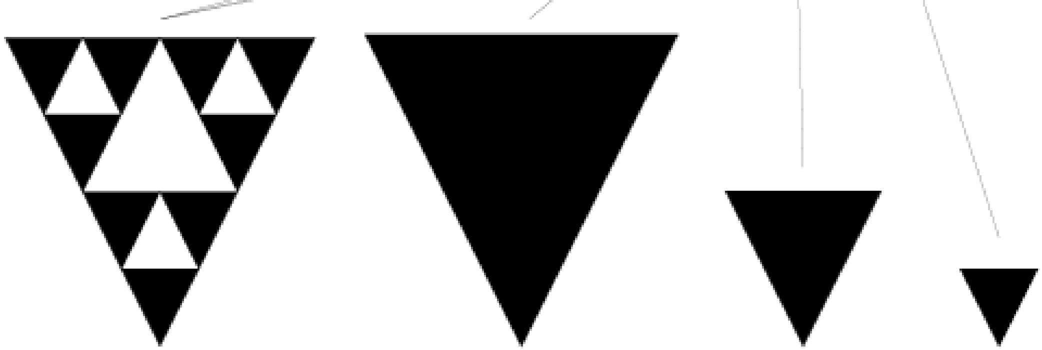
Sierpinski Sieve Dipole Antennas

Main Benefit: Multiband

The 3 bands matched by 3 different bowtie dipoles

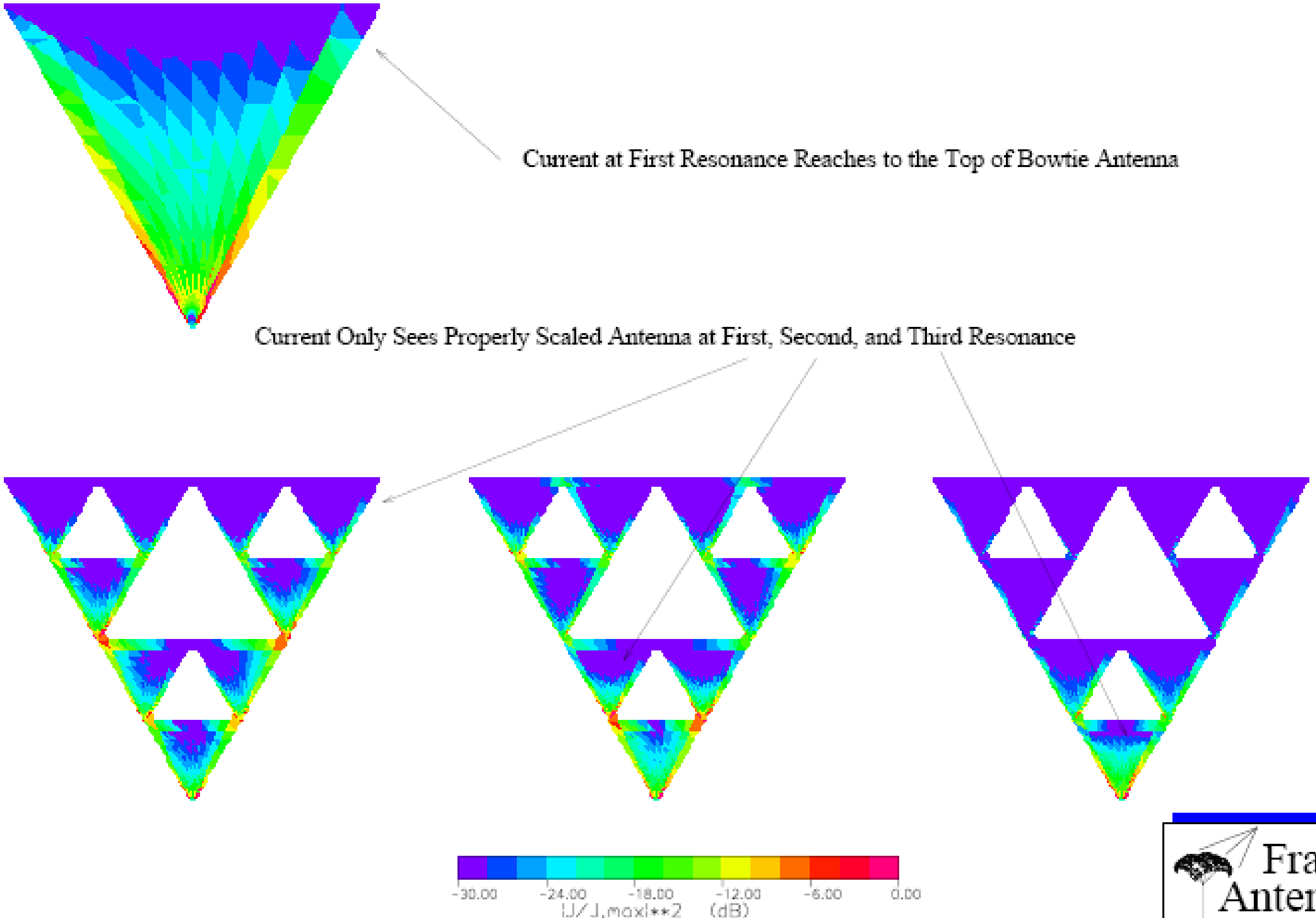
Are matched by 1 sierpinski dipole





Surface Currents Computed by Method of Moments

Surface Currents Clearly Show Multiband Behavior



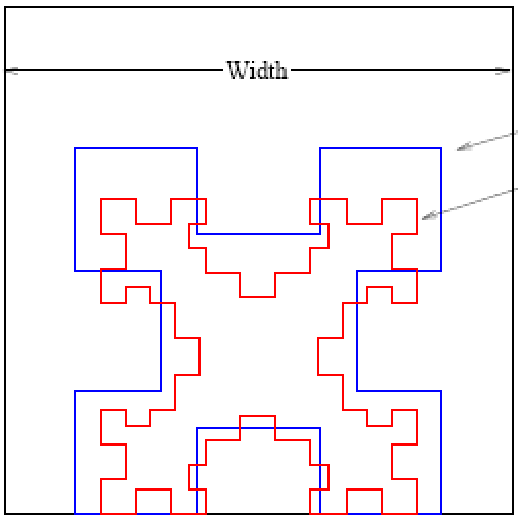
Fractal Antennas

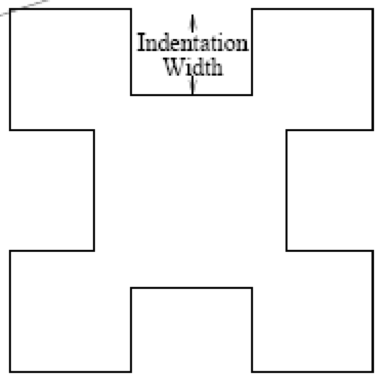
Fractal Square Loop Antennas

Main Benefit: Decreased Size

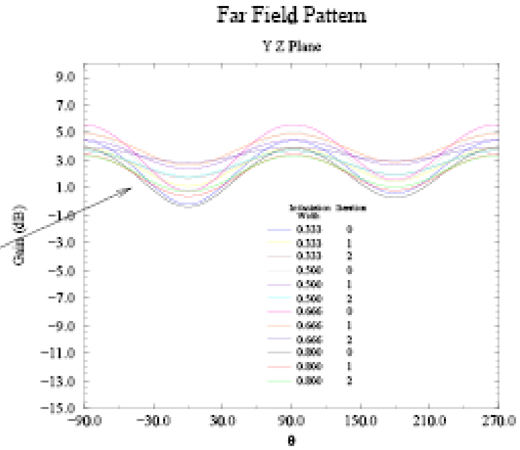
Decreased Antenna Width
Accompanies Increases in Iteration

For Second and Third Iteration





Far Field Pattern
Remains Similar
even with
Smaller Area



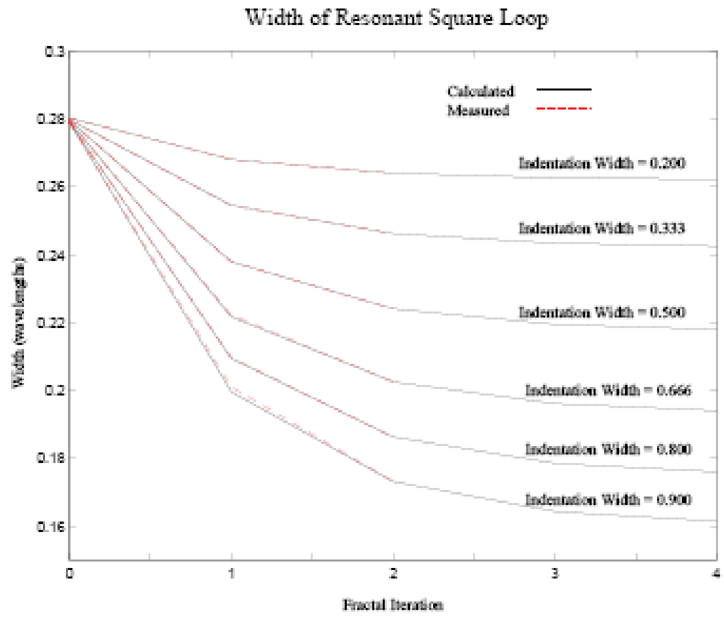
Fractal
Antennas

Fractal Square Loop Antenna Design Curves

The Antenna can be Fabricated for a Given Iteration

$$Width = \frac{C}{e^{2 \cdot 1.1} - 1}$$

For a given indentation width, resonant loops can be designed using the above equation, where C is found empirically.

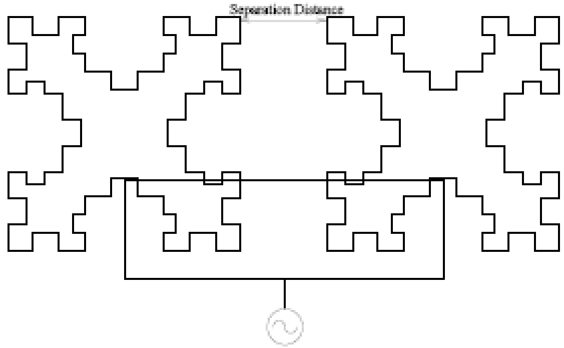


Fractal Antennas

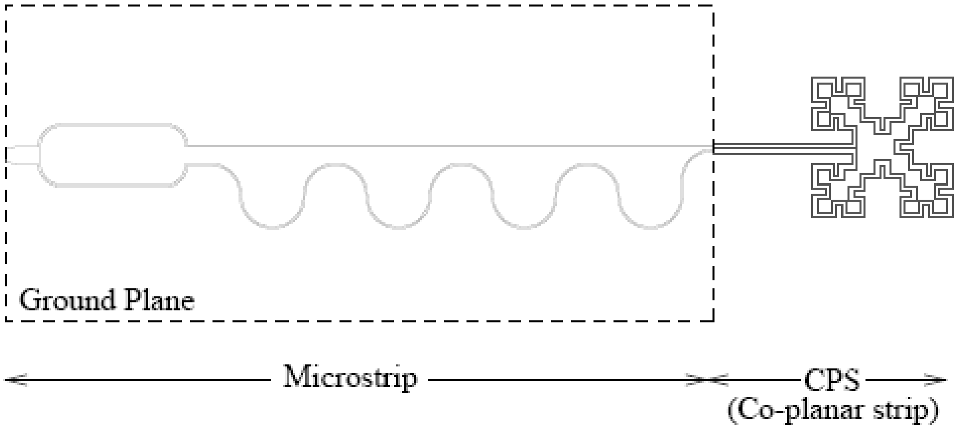
Arrays with Fractal Elements

Main Benefit: Decreases Mutual Coupling between Elements

Separation Distance can be Maximized Using Fractal Elements



Thin Feeding Network for Fractal Array Elements

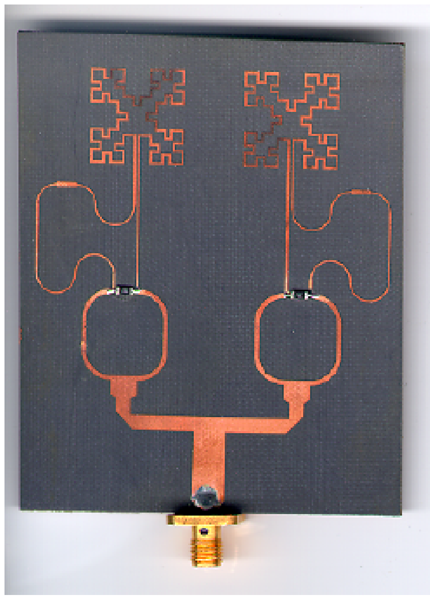


Fractal Antennas

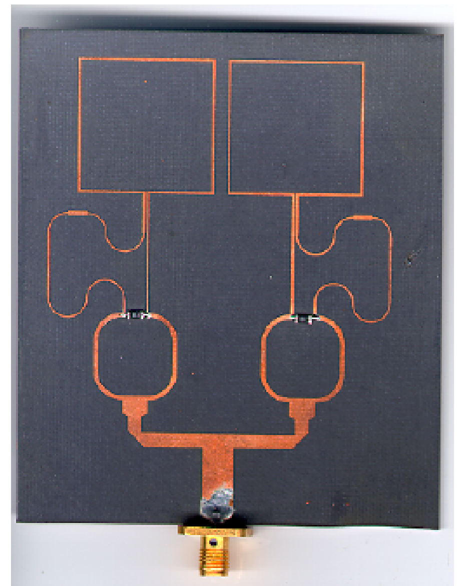
John Gianvittorio - UCLA

Fabricated Fractal Array Antennas

Decreased inter-element coupling for fixed spacing
Increased packing ability with smaller fractal elements



Fractal Array

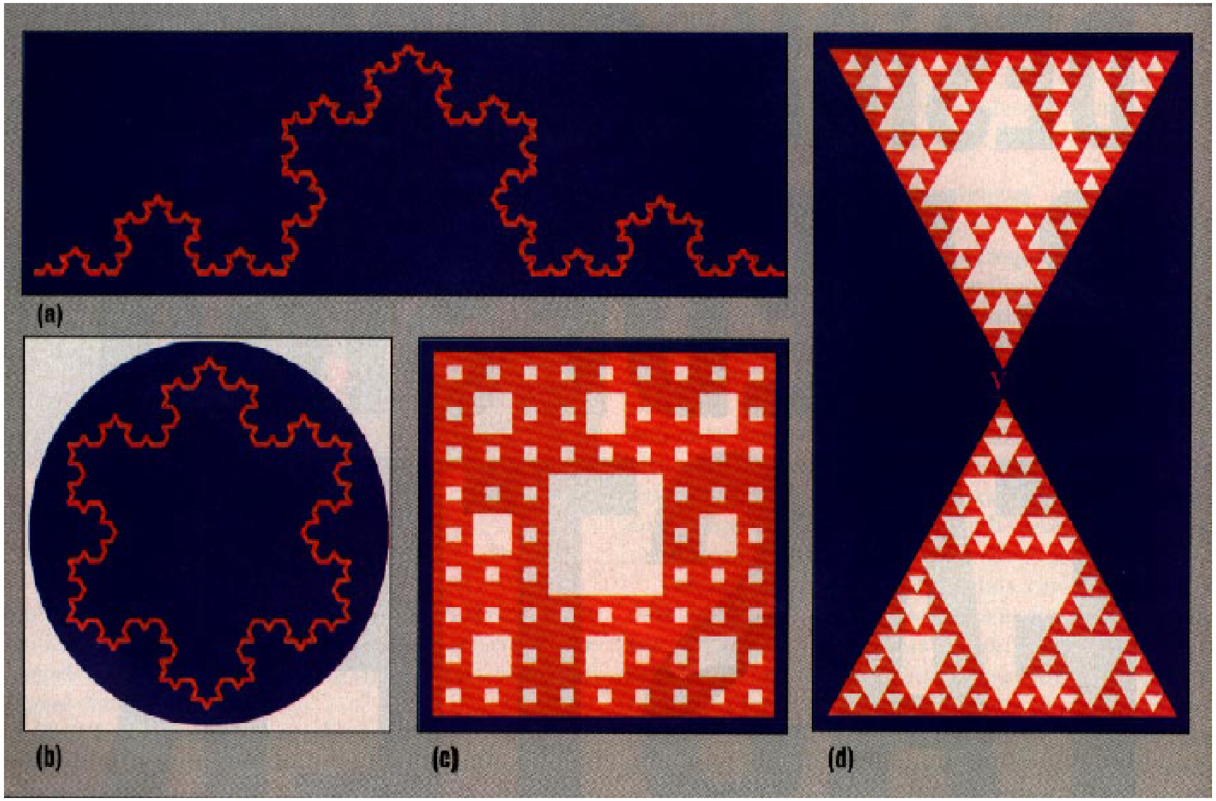


Standard Array

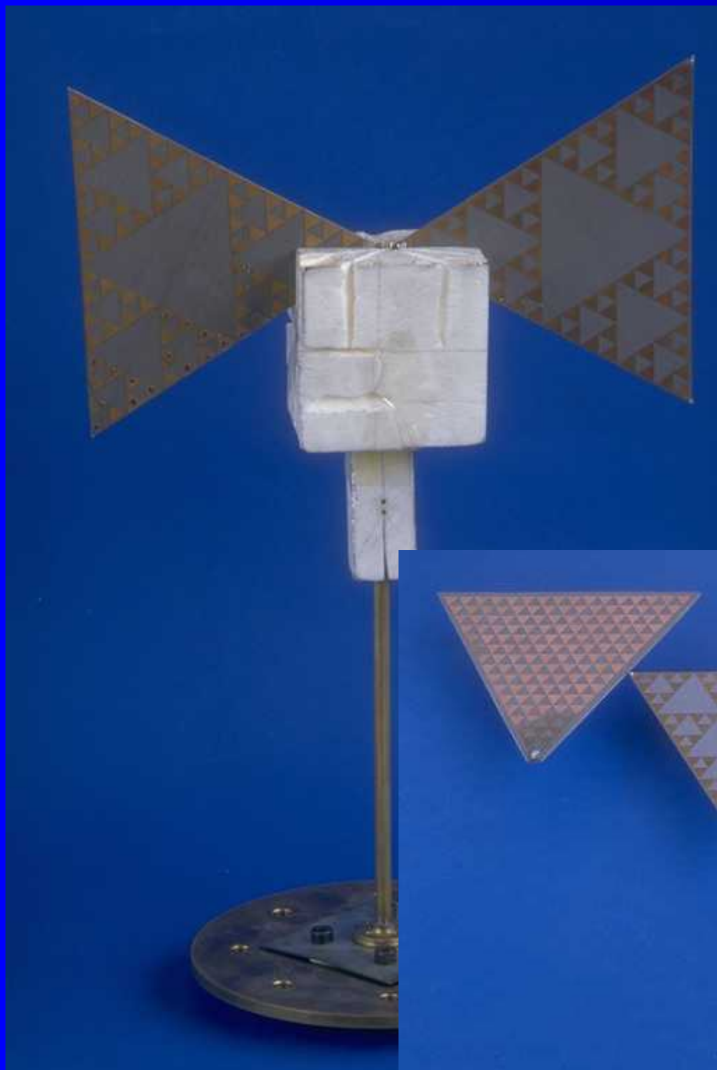
Fractal Antennas

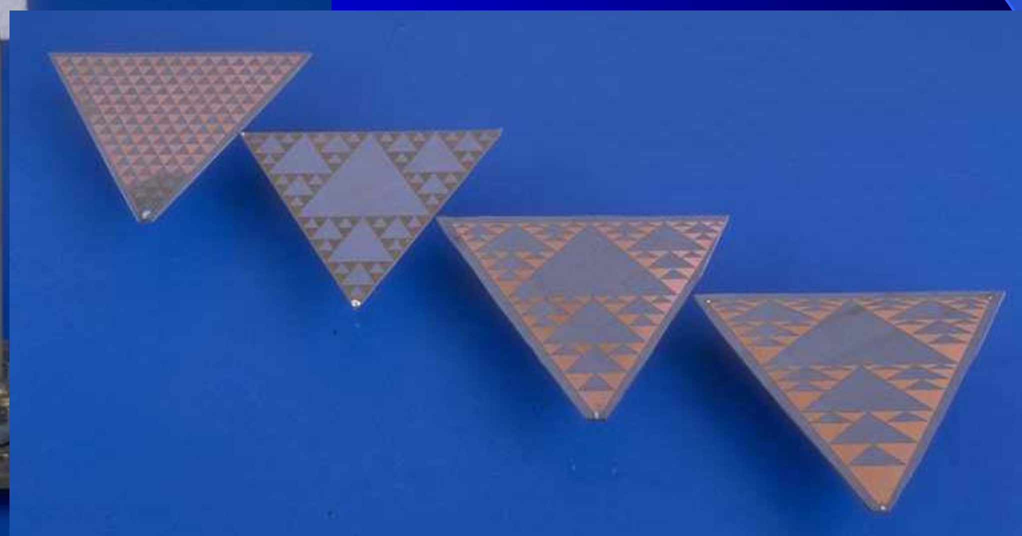
Fractal antenna design

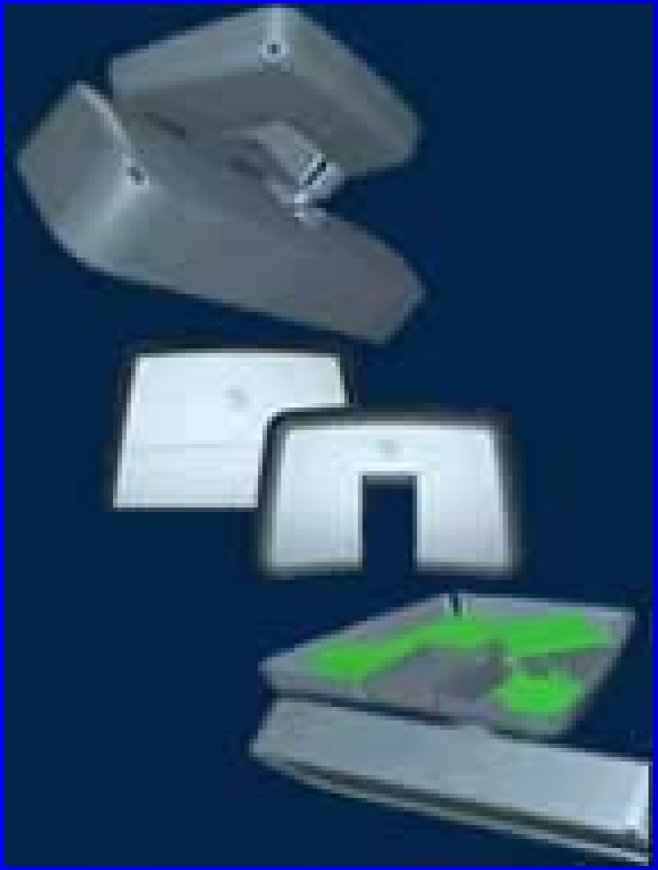
- Sample fractal antenna elements:

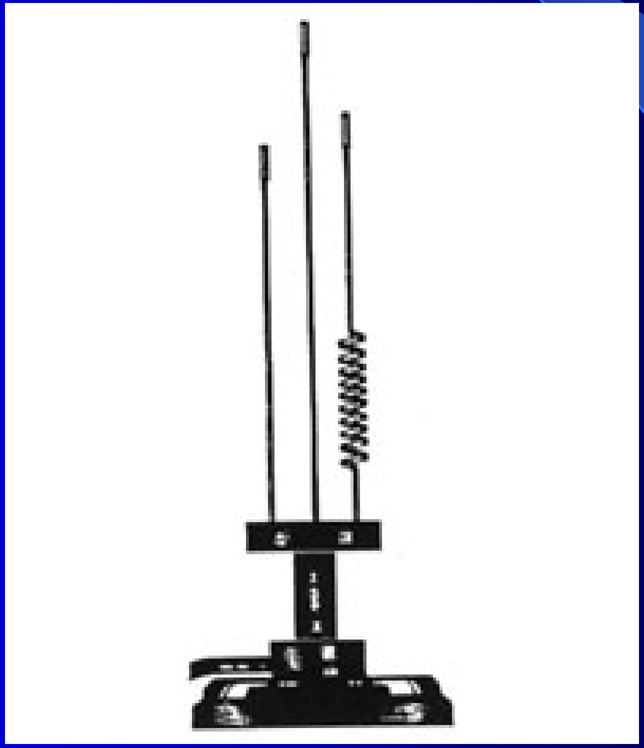


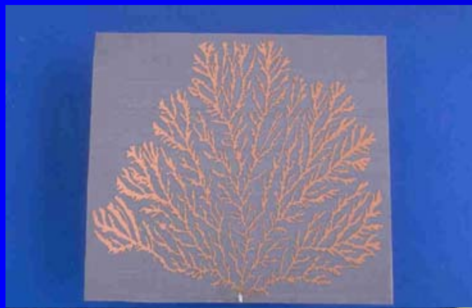
(a) Koch dipole (b) Koch loop (c) Cantor slot patch (d) Sierpinski dipole

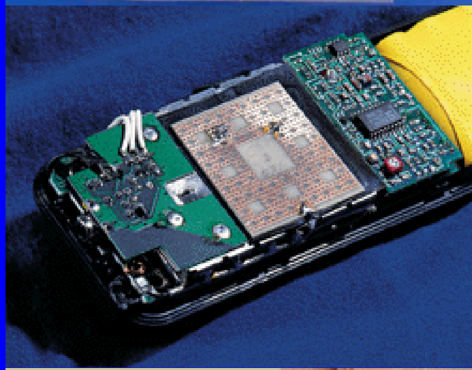


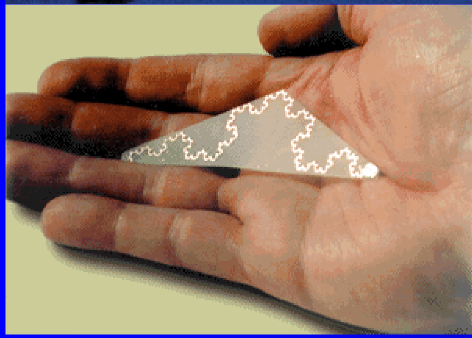








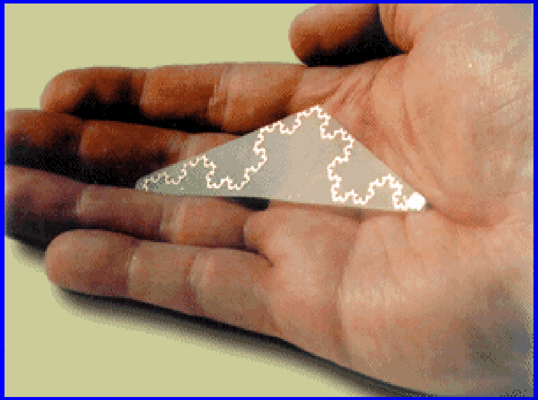


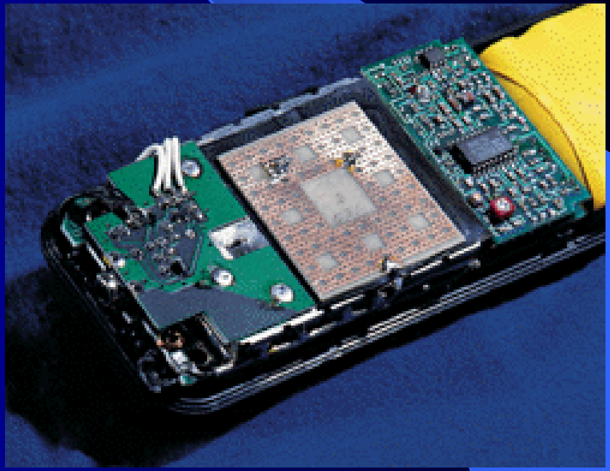


- Fractal antennas have superior multiband performance and are typically two-to-four times smaller than traditional aerials.
- Fractal antennas are the unique wideband enabler—one antenna replaces many.
- Multiband performance is at non-harmonic frequencies, and at higher frequencies the FEA is naturally broadband. Polarization and phasing of FEAs also are possible.

Fractal Antenna

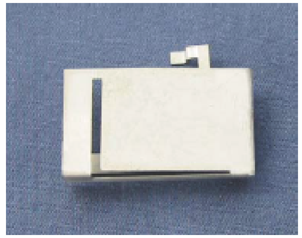
- Practical shrinkage of 2-4 times are realizable for acceptable performance.
- Smaller, but even better performance





EM-900M-1800U-1900U *Element*
EM-900M-1800U-1900U-A *Antenna Assembly*

900/1800/1900 MHz Tri-Band Antenna for GSM/DCS/PCS Wireless Applications



Features

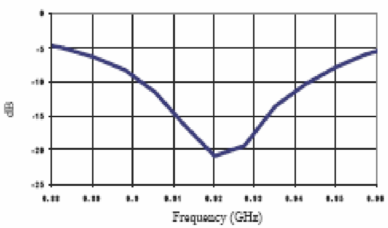
- *Efficient MLA Technology*
- *GSM/DCS/PCS Bands*
- *Peak Gain 0 dBi at 920 MHz*
- *Peak Gain 3 dBi at 1800 MHz*
- *Peak Gain 3 dBi at 1900 MHz*
- *Low Profile of less than 4.4 mm for Embedded Applications—1800 mm³*

This 900/1800/1900 MHz antenna is designed using SkyCross' patented MLA technology, providing superior efficiency and gain directivity in a small package. This antenna is the best performance solution for developers implementing a tri-band wireless system in the GSM, DCS and PCS bands where space is at a premium.

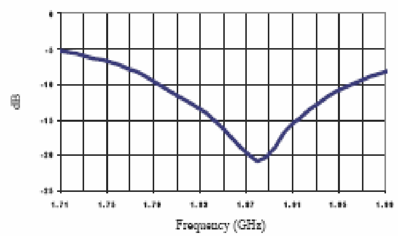
Electrical Specifications	
Frequency Range	880—960 MHz 1710—1880 MHz 1850-1990 MHz
Peak Gain	0 dBi at 920 MHz 3 dBi at 1800 MHz 3 dBi at 1900 MHz
VSWR	<3.5:1 GSM at band edges <3.5:1 DCS at band edges <2.5:1 PCS at band edges
Polarization	Linear
Azimuth Pattern	Omni-directional
Feed Impedance	50 Ohms Unbalanced

Mechanical Specifications	
Size	.97 x 0.51* x 0.17 inches 24.6 x 13.0* x 4.3 mm *width dimension does not include feed
Weight	0.8 g

Low Band Return Loss



High Band Return loss



FRACTAL AND SPACE-FILLING TRANSMISSION LINES, RESONATORS, FILTERS AND PASSIVE NETWORK ELEMENTS

WO0154221

PUENTE BALIARDA CARLES [ES]; O'CALLAGHAN CASTELLA JUAN MANU [ES]; ROZAN EDOUARD JEAN LOUIS [ES]; COLLADO GOMEZ JUAN CARLOS [ES]; DUFFO UBEDA NURIA [ES]

FRACTUS S.A., Barcelona

This invention relates to high frequency electromagnetic circuits, in particular to those made on planar or quasi-planar substrates, where the circuit is patterned on a metallic or superconducting film on top of a dielectric in any of the configurations known to those skilled in the art (for instance micro-strip, strip-line, co-planar, parallel plate or slot-line configurations). A part of the circuit such as the characteristic strip or slot of said configurations is shaped in a novel space-filling or fractal geometry which allows a significant size reduction of the circuital component. Miniature transmission lines, capacitors, inductors, resistors, filters and oscillators can be manufactured this way.

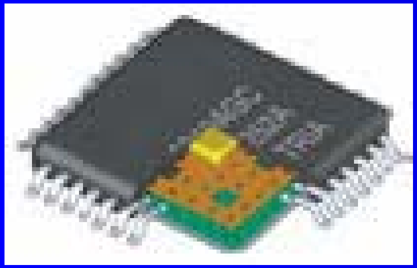
Also **NATHAN COHEN**, *CTO, Fractal Antenna Systems, Inc., 300 Commercial Street, Suite 27, Malden MA 02148 ; (617) 381-9595, FAX: (617) 489-6207*. Fractal Antenna Website: http://www.fractenna.com.

Put the Antenna in the Package

The next major opportunity for wireless component manufacturers is to put the antenna into the package. Fractal-technology applied to antennas reaches the required miniaturisaton to make Full Wireless System in Package (FWSiP) a reality.

FracWaveTM technology

Fractus is the worldwide pioneer in the application of fractal geometries to antenna design and production. The space-filling properties of fractals enable the production of miniature antennas with optimal performance, and with multi-band capabilities. FracWaveTM Antenna in Package (AiP) technology is suitable for Bluetooth®, WLAN, GPS, UWB and Zigbee and for sensors for automotive, biomedical and industrial purposes.

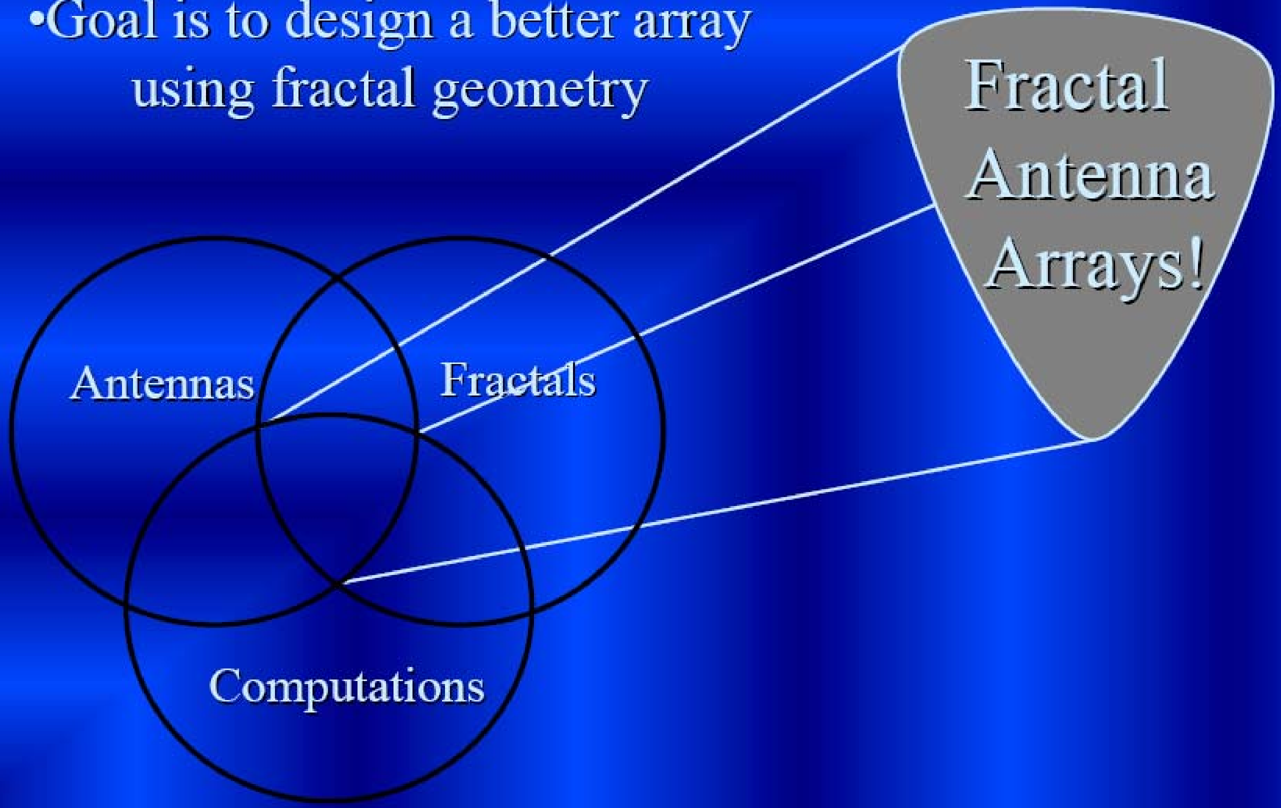


Visualization of antenna (the brown layer) integrated on a package substrate

AiP integrated on Bluetooth® adapter

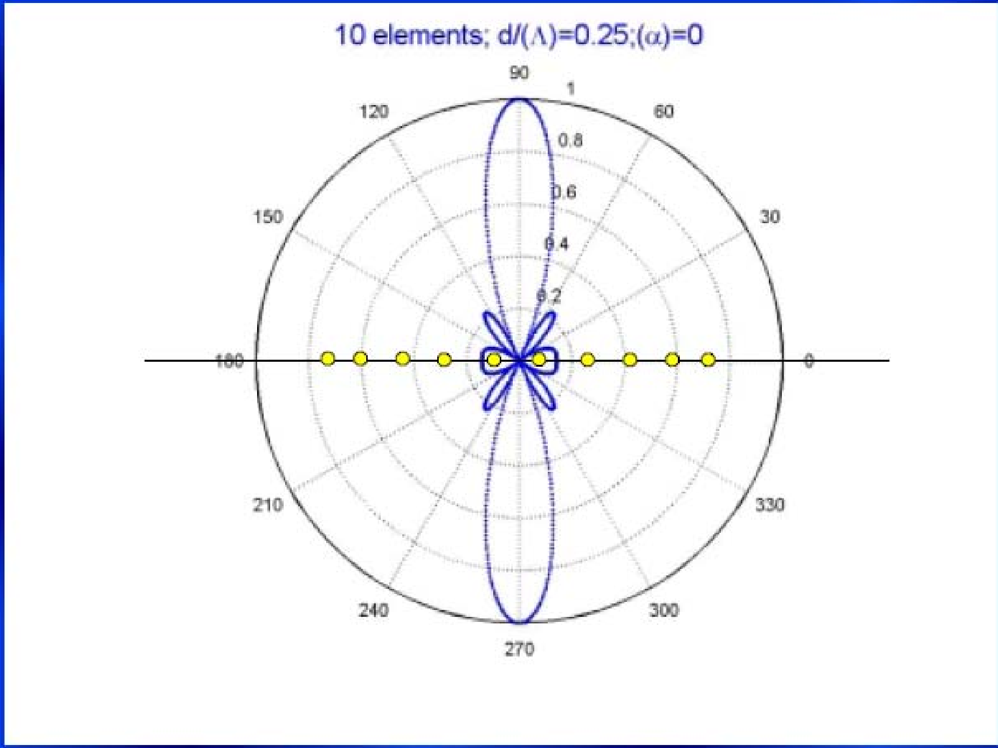
"How does it all come together?"

- Goal is to design a better array using fractal geometry



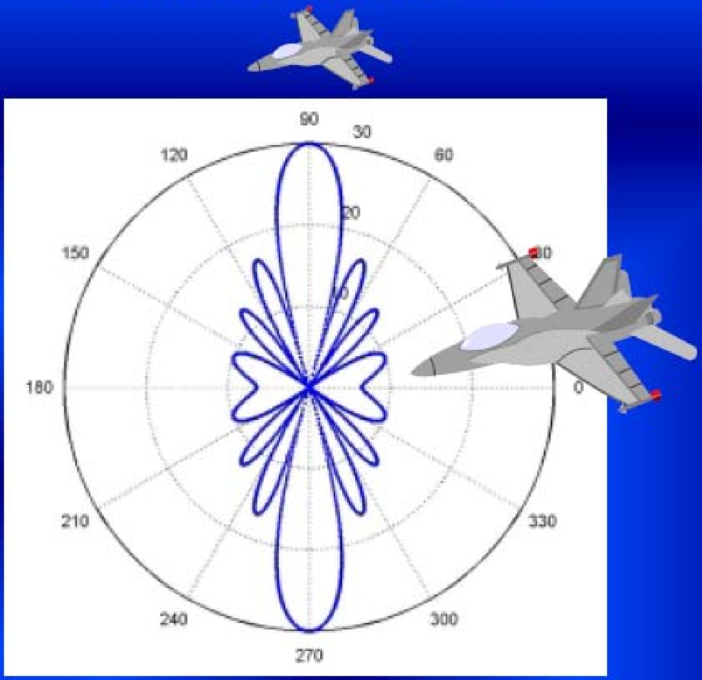
Radiation

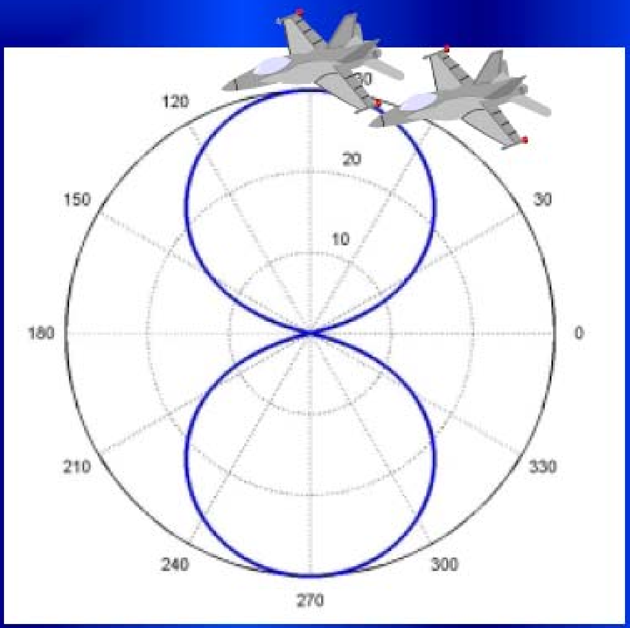
- Linear Antenna Array



An Ideal Array and Why

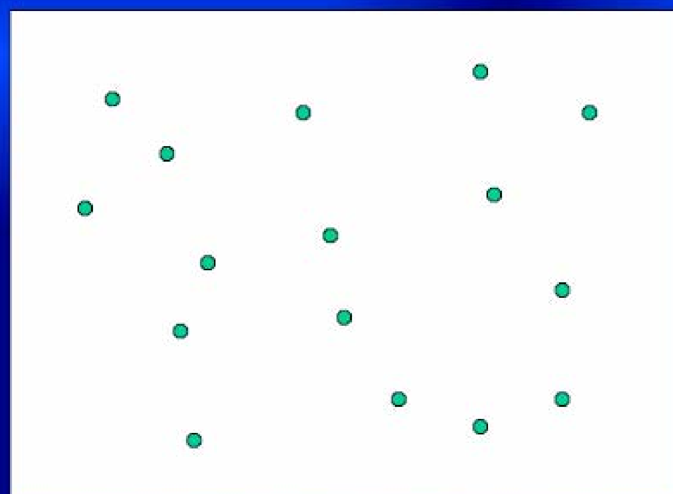
- Low/no side lobes
- Good quality main beam



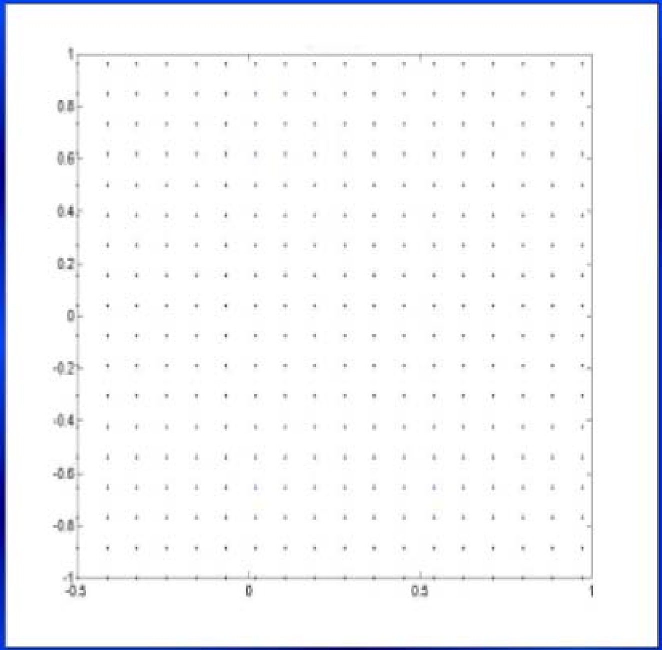


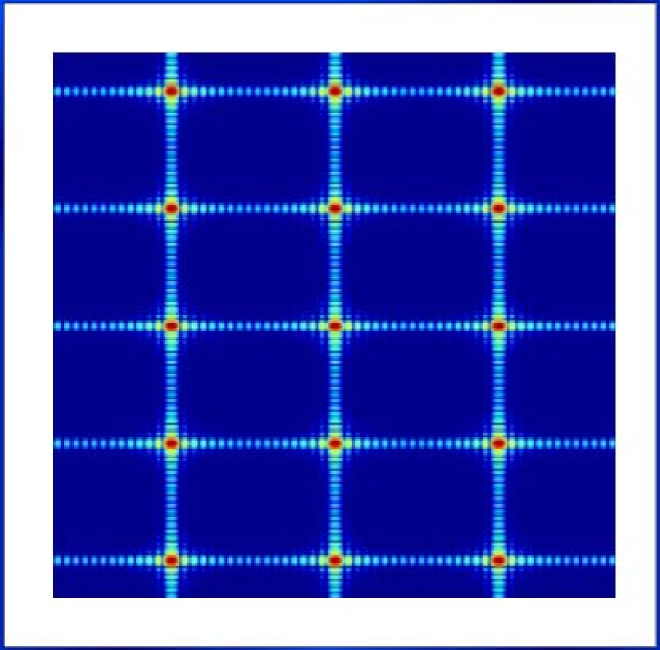
More Radiation

- Periodic Array
- Random Array

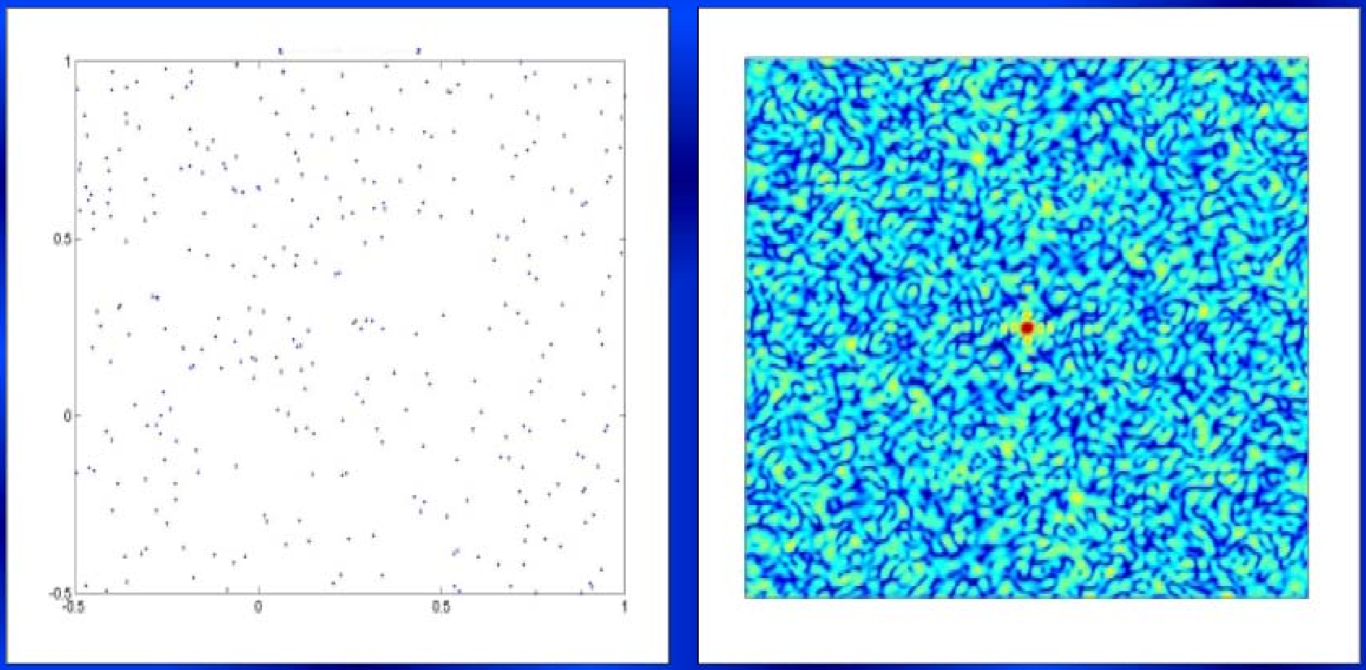


Ordered Planar Array

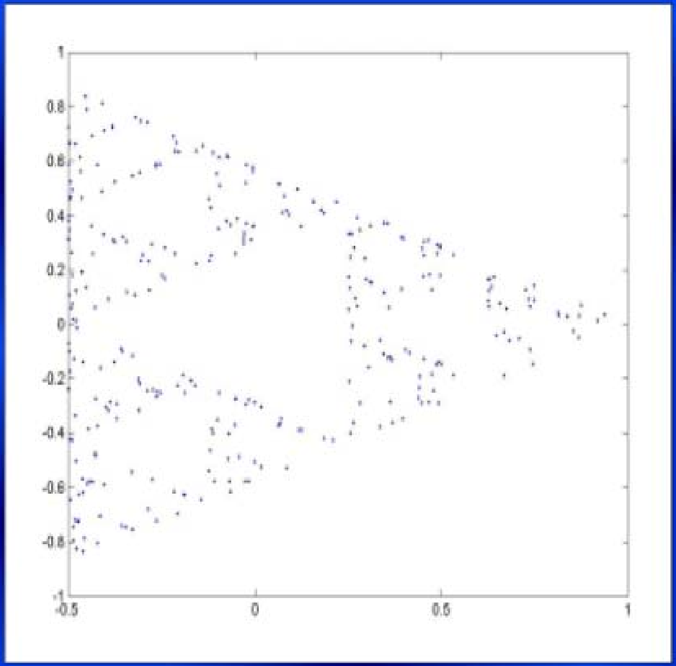


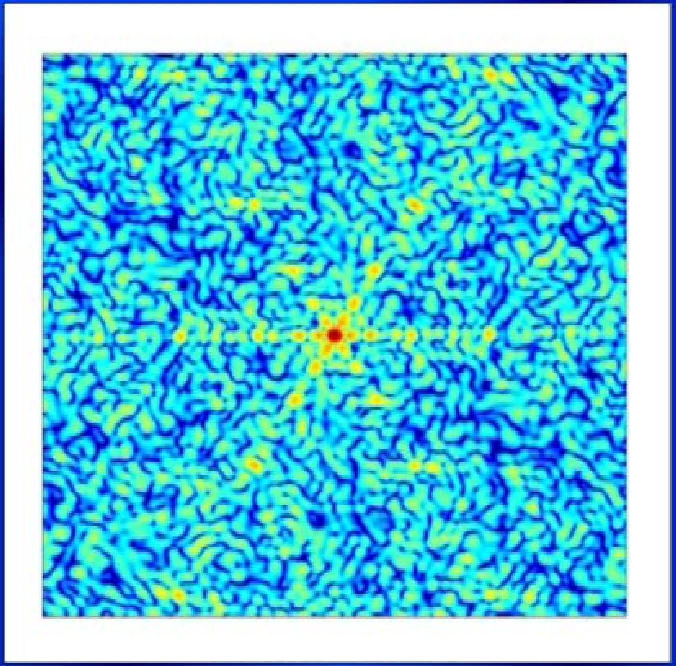


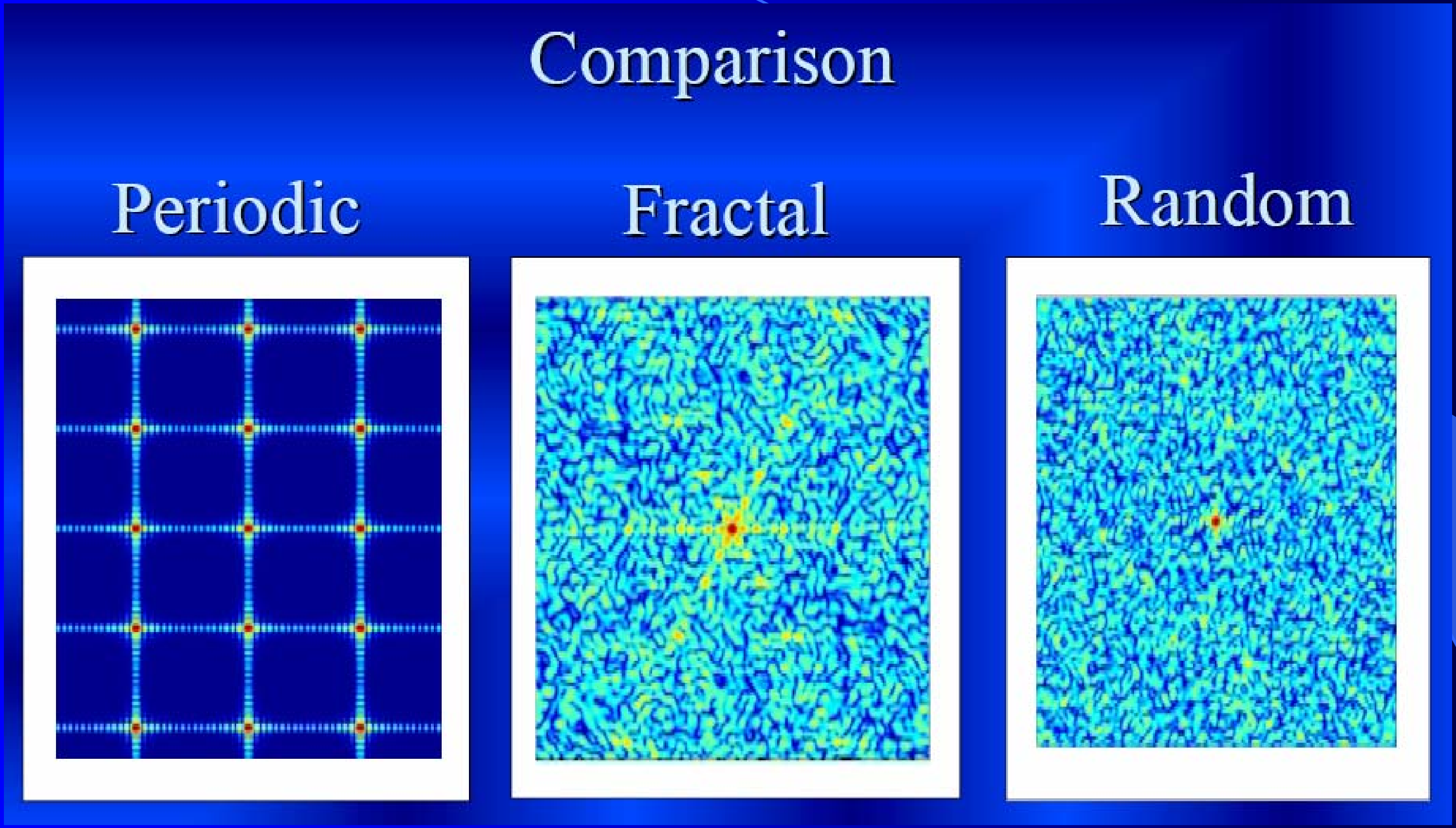
Randomized Planar Array

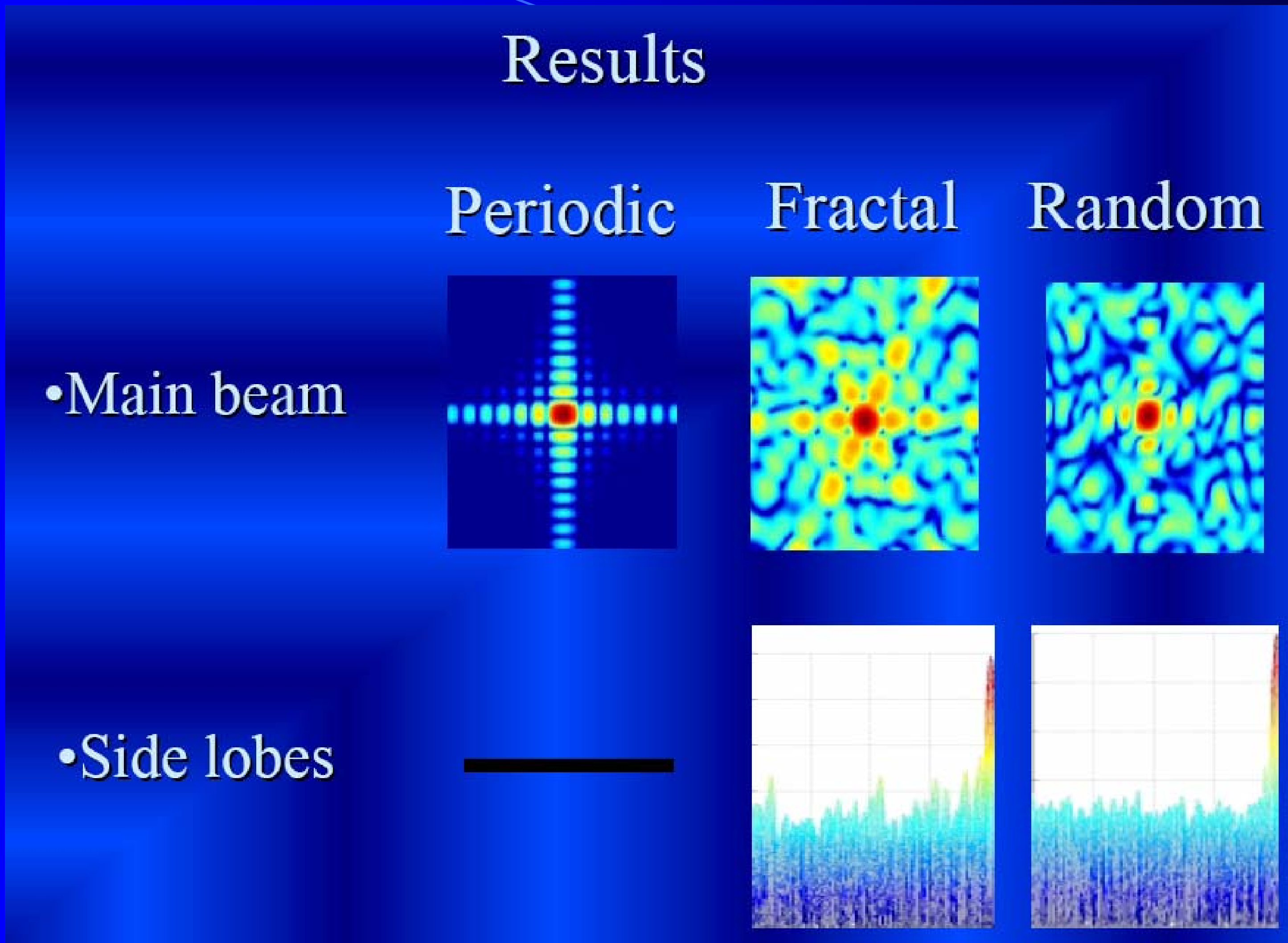


Fractal Planar Array






Comparison
Periodic
Fractal
Random


Results
Periodic
Fractal
Random
•Main beam
•Side lobes

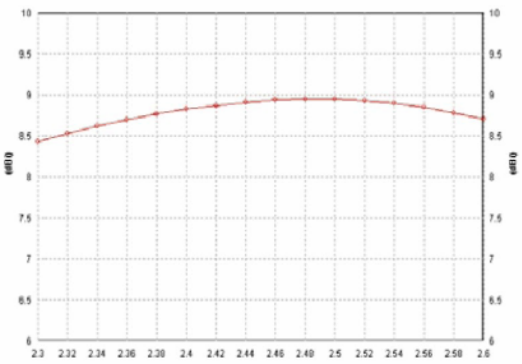
Fractus® Julia-12 ISM 2.4 GHz VPol   P/N: FR03-02-N-0-002

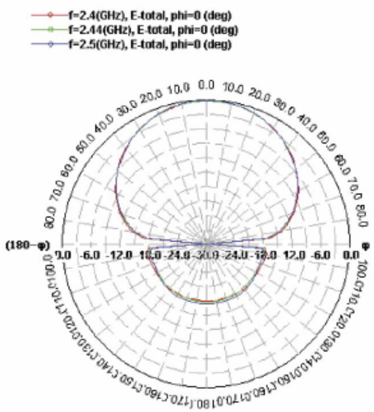
The **JULIA-12 ISM 2.4 GHz panel antenna** is a cost effective solution with an excellent broad coverage in a tiny package. The antenna features an internal Fractal shaped element and is suitable for both indoor and outdoor aplications.

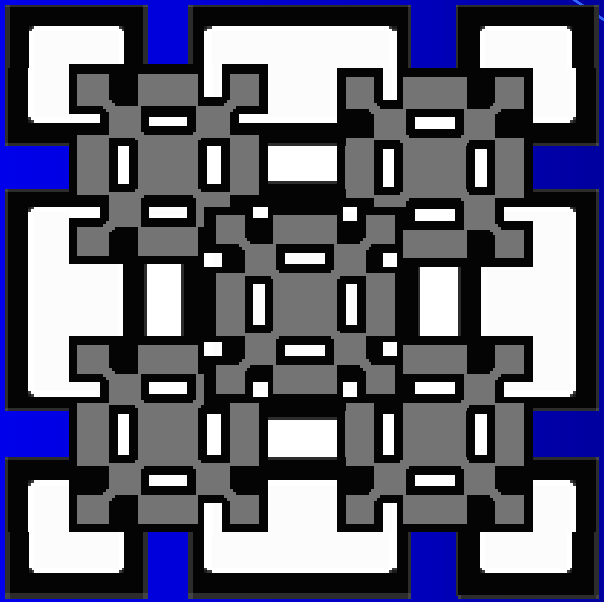
Frequency Range	2.4 - 2.5 GHz
Directivity/Gain	9.6 dBi / 8.8 dBi
Impedance	50 Ω
Polarisation	VPOL
F/B Ratio	> 18 dB
VSWR	< 1.5 : 1
Vertical Beamwith	65°
Horizontal Beamwith	70°
Connector (Pig Tail)	RP-TNC or RP-SMA
Radome	ABS
Dimensions	10 x 10 x 3 cm

Measured results from a standard

Patent Pending: WO0154225, WO0122528, PCT/EP01/10589, PCT/EP02/07837, US60/613394, US60/627653 and PCT/EP02/07836







Fractus® Julia-10b ISM 2.4 GHz VPol

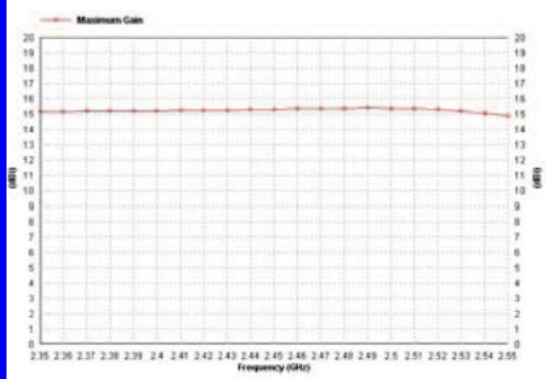
P/N: FR03-02-N-0-003

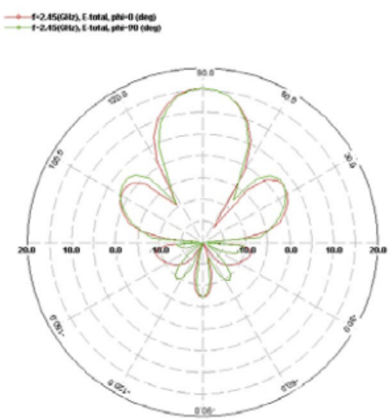
The **JULIA-10 ISM 2.4 GHz panel antenna** offers a superior gain to size ratio thanks to the Fractus' patented "Super Directive" patch design. JULIA-10 is the ideal choice to get extra range capacity in a tiny package.

Frequency Range	2.4 - 2.5 GHz
Directivity/Gain	16 dBi / 15 dBi
Impedance	50 Ω
Polarisation	VPOL
F/B Ratio	> 20 dB
VSWR	< 1.5 : 1
Vertical Beamwith	30°
Horizontal Beamwith	35°
Connector (Pig Tail)	RP-TNC or RP-SMA
Radome	ABS
Dimensions	21 x 21 x 3 cm

Measured results from a standard

Patent Pending: WO0154225, WO0122528, PCT/EP01/10589, PCT/EP02/07837, US60/613394, US60/627653 and PCT/EP02/07836





Fractal Geofind™ GPS Slim Chip Antenna — P/N: FR05-S1-E-0-103

The **Fractal Geofind** is an slim chip antenna engineered specifically for consumer electronic devices operating with GPS system where low-cost and robust performance is mandatory.

Taking advantage of the space-filling properties of fractals, this **small planar monopole** antenna is ideal for use low-cost consumer electronic devices to add personal location functionalities. The **Fractal Geofind GPS Slim Chip Antenna** speeds your time-to-market by allowing you to integrate it within your industrial design easily (SMD mounting) and efficiently.

10 x 10 x 0.9 mm (image karger than actual size)

Front   Back

Patent Pending: WO0154225, WO0122528, PCT/EP01/10589, PCT/EP02/07837, US60/613394, US60/627653 and PCT/EP02/07836

Product Benefits

High performance/price ratio

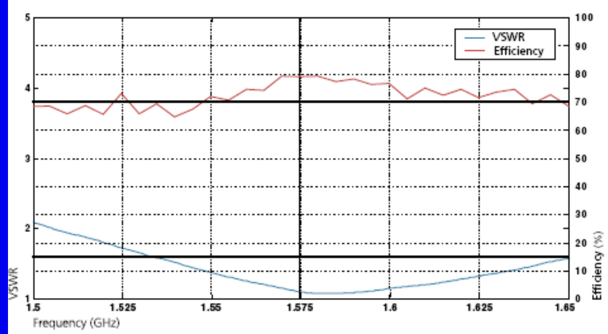
Raises your device's competitiveness by increasing satellite sensitivity and decreasing your device's BoM cost.

Omnidirectional pattern

Optimises device usage due to a uniform radiation pattern.

Small Volume

Allows integration into space limited areas easily and efficiently.



Frequency Range	1575 MHz
Efficiency	> 70 %
Peak Gain	> 1 dBi
VSWR	< 1.6:1
Weight	0.20 g
Temperature	-40 to +85 °C
Impedance	50 Ω unbalanced
Dimensions	10 x 10 x 0.9 mm

Measured results from a standard PCB of 70x30 mm

Please contact your sales representative at Richardson Electronics to obtain additional information on recommended configurations for different UWB devices.
Richardson Electronics: **www.rell.com** Fractus: **wireless@fractus.com** Reference: **DS_FR05-S1-E-0-103_v01**

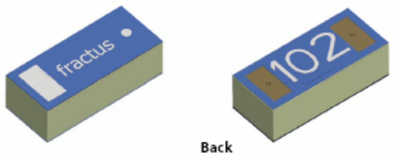
Fractus® Compact Reach Xtend™ Chip Antenna — P/N: FR05-S1-N-0-102

The **Fractus Compact Reach Xtend Chip Antenna** for Bluetooth® and 802.11 b/g WLAN is a tiny rectangular 3D-shaped antenna suitable for headset, compact flash (CF), secure digital (SD) and other small PCB devices operating at 2.4 GHz where high performance and low-cost are mandatory. Its broad bandwidth ensures high quality signal reception and transmission across wireless devices and different plastic housing designs.

Taking advantage of the space-filling properties of fractals, this **small mono-pole** antenna is ideal for use within indoor (highly scattered) environments. The **Fractus Compact Reach Xtend Chip Antenna** speeds your time to market by allowing you to easily integrate it within your industrial design (SMD mounting).

7 x 3 x 2 mm (image larger than actual size)

RoHS



Front **Back**

Patent Pending: WO0154225, WO0122528, PCT/EP01/10589, PCT/EP02/07837, US60/613394, US60/627653 and PCT/EP02/07836

Product Benefits

Small form factor

Allows integration into space limited areas easily and efficiently with minimum clearance area.

Broad bandwidth

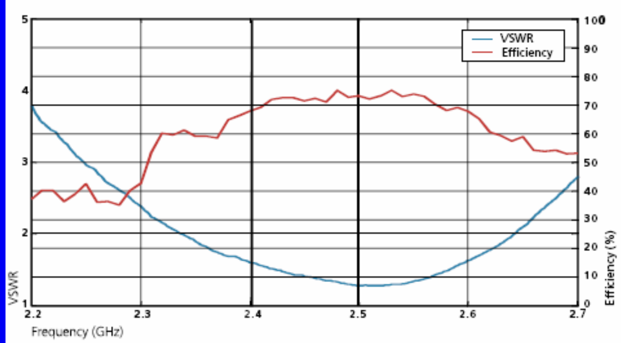
Ensures robust performance when considering different plastic housing and close body proximity.

Omnidirectional pattern

Optimises device usage due to a uniform radiation pattern.

Multi-mode support

Works for Bluetooth, and Wi-Fi 802.11b and g standards.



Frequency Range	2.4 - 2.5 GHz
Efficiency	> 70 %
Peak Gain	> 1 dBi
VSWR	< 2:1
Weight	0.20 g
Temperature	-40 to +85 °C
Impedance	50 Ω unbalanced
Dimensions	10 x 10 x 0.8 mm

Measured results from a standard PCB of 47x23 mm

Please contact your sales representative at Richardson Electronics to obtain additional information on recommended configurations for different UWB devices.
Richardson Electronics: **www.rell.com** Fractus: **wireless@fractus.com** Reference: **DS_FR05-S1-N-0-102_v01**

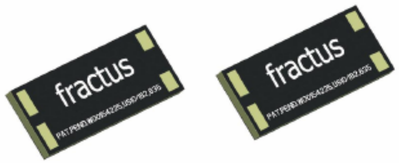
Fractus® EZConnect™ Zigbee™ Chip Antenna

P/N: FR05-S1-R-0-105

The Fractus **EZConnect Zigbee Chip Antenna** is a compact rectangular antenna suitable for smart home, security and other industrial devices using the 915 MHz ISM band, where low power consumption and cost are top of mind.Taking advantage of the space-filling properties of fractals, this **compact monopole** antenna is ideal for use within indoor (highly scattered) as well as outdoor environments.

The **Fractus EZConnect Zigbee Chip Antenna** speeds your time to market by allowing you to easily integrate it within your industrial design (SMD mounting).

18 x 7,3 x 1 mm (image larger than actual size)



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Patent Pending: WO0154225, WO0122528, PCT/EP01/10589, PCT/EP02/07837, US60/613394, US60/627653 and PCT/EP02/07836

Product Benefits

Small form factor

Allows integration into space limited areas easily and effectively.

Broad bandwidth

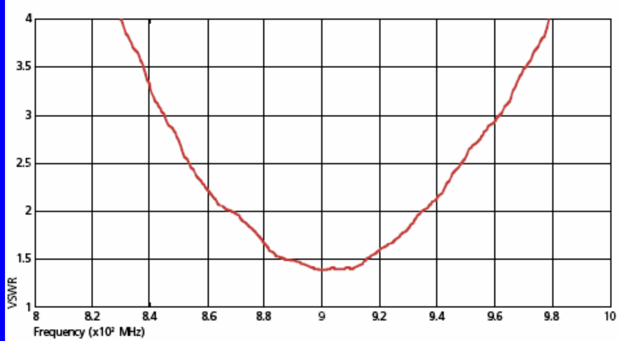
Ensures robust performance in different PCB dimensions and plastic housing, without the need for a matching network.

High performance

Optimises power consumption and increases device range.

Omnidirectional pattern

Increases device robustness due to a uniform radiation pattern.



Frequency Range	902 - 928 MHz
Efficiency	> 40 %
Peak Gain	> 0 dBi
VSWR	< 2:1
Weight	0.20 g
Temperature	-40 to +85 °C
Impedance	50 Ω unbalanced
Dimensions	18 x 7,3 x 1 mm

Measured results from a standard PCB of 120x65 mm

Please contact your sales representative at Richardson Electronics to obtain additional information on recommended configurations for different UWB devices.
Richardson Electronics: **www.rell.com** Fractus: **wireless@fractus.com** Reference: **DS_FR05-S1-E-0-105_v01**

Customised Mobile Handset Antenna
Pat. Pending: WO012258, VS2002140615, WO0154225, VS10/182,635

Fractus Compact Dual-Band Reach XtendTM WLAM 802.11 a/b/g/j/n Chip Antenna 2.4 & 5GHz

FRACTAL ANTENNA SYSTEMS INC

Electronic Warfare

UAB™ Antenna

Extreme wideband and omnidirectional performance with superior gain. Operates with or without a ground plane over a 25:1 frequency range, from VHF to microwave. Compact form factor packaged in a 7.7 inch-diameter, 10 inch-high radome weighing 4.8 pounds. Up to 250W input power. VSWR less than 2:1.

UAD™ Antenna

Extreme wideband performance with up to 250W power handling and superior gain. Operates over UHF to microwave. Low profile of 5.7 inches and easily concealable in a 7.7 inch-diameter radome. VSWR less than 2:1.

UGS™ Antenna

Single antenna integrated with an unattended ground sensor (UGS) providing superior omnidirectional long-range performance. Operates over high HF through VHF. Innovative raised phase center design minimizes ground losses, while improving radiation pattern and launch angle. Easily deployed in a compact, lightweight package measuring 2.5 inches in diameter and 3 feet in height.

RFsabre™

With outstanding lower frequency gain and less than 3:1 VSWR over a very wide frequency range, the RFsabre antenna delivers great performance in a distinctly compact form factor. The vehicle-mounted version can survive impacts with solid objects at speeds up to 25 MPH. Geared for security, communications, signal gathering, and high power transmit applications. New hanging or tripod mounted versions available.

TRANZTENNA™

Breakthrough performance in a wideband antenna from the fractal antenna innovators

Fractal antenna technology, implemented in transparent conductive film, makes covert capability possible with a mission-capable antenna system that operates over a huge frequency range.

- Outstanding gain
- Transparent
- Conformable
- Only 13 x 18 inches
- VSWR less than 3:1
- Inherently 50 Ohms
- Optional frequency lowering panels

Signal intelligence warfighters face a difficult challenge — the need to monitor communications over a very wide frequency range while remaining clandestine. Current electronic surveillance systems employ multiple antennas that are either large or noisy. Covertness and high performance are united in the Tranztenna™ optically transparent antenna: an extremely wideband antenna designed for vehicle or building window placement. This conformable, rugged, compact antenna is easy to transport and install in field operations. New missions to intercept and monitor enemy communications are possible with this breakthrough in transparent antenna technology.

Feature	Advantage	Benefit
Transparent	Visually unobtrusive	Covert use of antenna in vehicle or building window
Good Gain	Superior to ITO films	Excellent signal-to-noise ratio
Wideband	Operation over very wide frequency range	Instantaneously access most spectrum of interest
Compact Size	Effective use of small window apertures	Access to lower frequencies
Conformable	Flexible sheet	Easy transport and deployment

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