Parul Dawar, N. S. Raghava, Asok De, 2017. Miniaturized UWB multi-resonance patch antenna loaded with novel modified H-shape SRR metamaterial for microspacecraft applications. *Frontiers of Information Technology & Electronic Engineering*, **18**(11): 1883-1891. http://dx.doi.org/10.1631/FITEE.1601193

Miniaturized UWB multi-resonance patch antenna loaded with novel modified H-shape SRR metamaterial for microspacecraft applications

Key words: Ultra-wideband; Antenna; Metamaterial

Corresponding author: Parul Dawar
E-mail: paru.dawar@gmail.com
ORCID: https://orcid.org/0000-0003-4073-9013

Motivation

- To determine feasibility of incorporating the concept of altering the bulk effective permittivity for broadening of bandwidth of antenna.

- ***To analyse different types and shapes of metamaterials for obtaining their frequency response through simulation and to extract material parameter of bulk composite host medium by parameter extraction (NRW method)***

- ***To design and construct reduced size and broad bandwidth antenna with metamaterials embedded in the middle of the substrate and validate by simulation and measurement.***

Implementation of the metamaterial approach is cheaper and maintains the planar nature of the microstrip antenna, which is essential for integration with microstrip circuits.

From the analysis of various shapes of metamaterials, an approximate design methodology for size reduction and bandwidth enhancement has been attempted.

Main idea

- Metamaterials that provide a structure with an effective negative index of refraction.

Timeline:

1968 — 1996 — 1999 — 2000 → Time

1968: Veselago first studies the effect a negative permittivity and permeability has on wave propagation

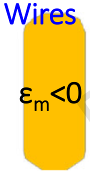
1996: Pendry proposes wire structures to realize a negative permittivity

1999: Pendry proposes Split Ring Resonators (SRR's) to realize a negative permeability

2000: Smith is the first in the world to physically realize a medium with an effective negative index of refraction

Electric Response

Metallic Wires

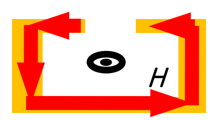


Collection of conducting wires forms an effective metal with a controllable plasma frequency.

$$\varepsilon_{eff} = 1 - \frac{\omega_P^2}{\omega^2}$$

ω_P: controllable plasma frequency

Magnetic Response



Split Ring Resonator (SRR)

Collection of SRR forms effective magnetic medium.

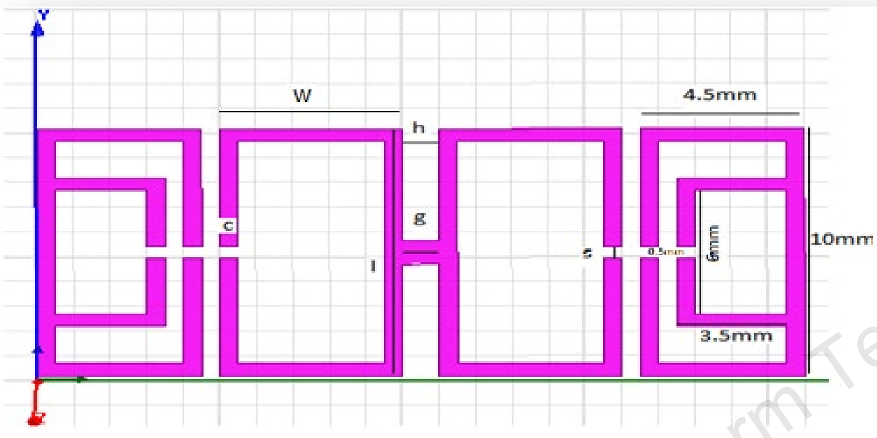
$$\mu_{eff} = 1 - \frac{F\omega^2}{\omega^2 - \omega_0^2 + i\omega\Gamma}$$

Γ: dissipation factor F: fractional factor

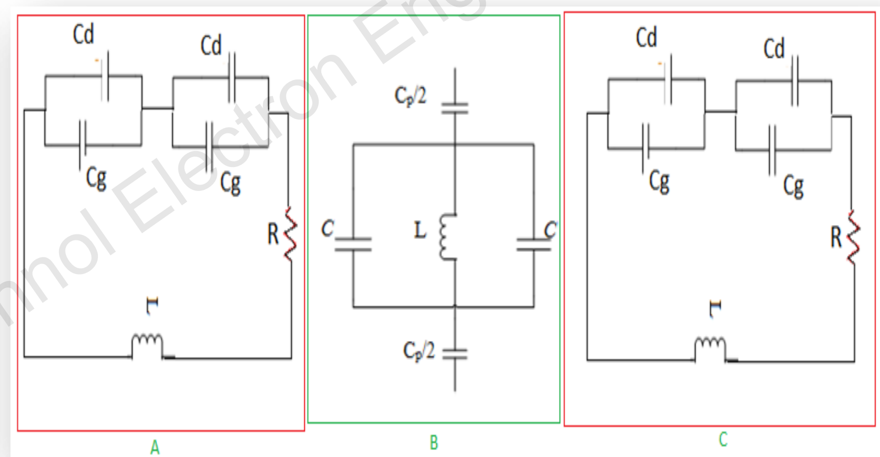
[V. G. Veselago. The electrodynamics of substances with simultaneously negative values of ε and μ. Soviet Physics-Uspekhi, 10(4):509–514, January-February 1968.]
[J. B. Pendry, A. J. Holden, W. J. Stewart, and I. Youngs, "Extremely low frequency plasmons in metallic micro structures," Phys. Rev. Lett., vol. 76, pp. 4773–4776, 1996.]
[J. B. Pendry, A. J. Holden, D. J. Robbins and W. J. Stewart, "Magnetism from conductors and enhanced nonlinear phenomena," *IEEE Trans. Microwave Theory Tech.,* vol. 47, pp. 2075-2084, Nov. 1999.]
[D. R. Smith,Willie J. Padilla, D. C. Vier, S. C. Nemat-Nasser, and S. Schultz," Composite Medium with Simultaneously Negative Permeability and Permittivity",Vol. 84, No. 18, Physical Review Letters,pp. 4184-4187,May 2000.]

Novel Modified H-shaped SRR metamaterial

It is composed of modified H-shaped resonating copper conductors placed between two modified SRR structures.



(a)Schematic view



(b) Equivalent circuit

l	10 mm
s	0.5 mm
c	1 mm
g	1 mm
h	1 mm
w	5 mm

(c)Design parameters.

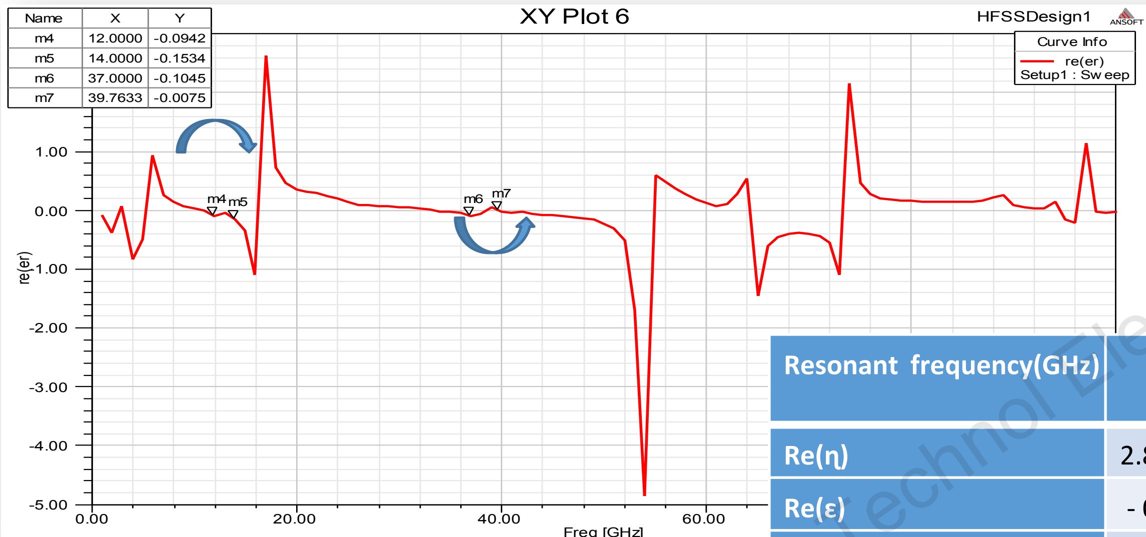
$$C = \varepsilon_0 \varepsilon_r \frac{A}{d} \qquad L = \mu_o t \left[\frac{2c}{2w+h} + \frac{\sqrt{(2w+h)^2 + l^2}}{c} \right]$$

$$C_p = \varepsilon_o \left[\frac{2w+h}{\pi} \ln \frac{2c}{a-l} \right]$$

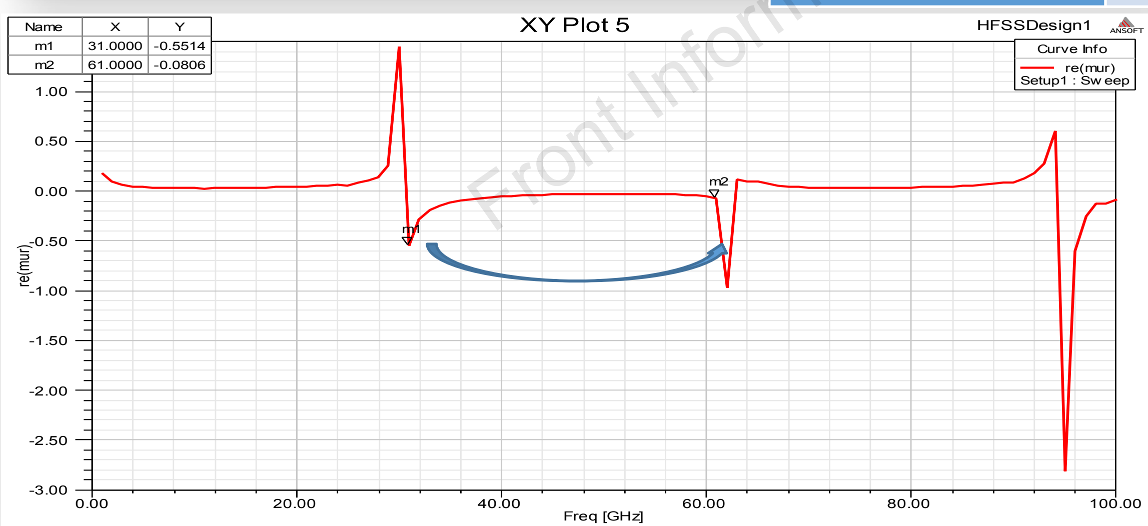
6% error

“Miniaturized UWB multi-resonance patch antenna loaded with novel modified H-shape SRR metamaterial for microspacecraft applications”, Frontiers of Information T
Electronic Engineering,SPRINGER,2017

Simulation results



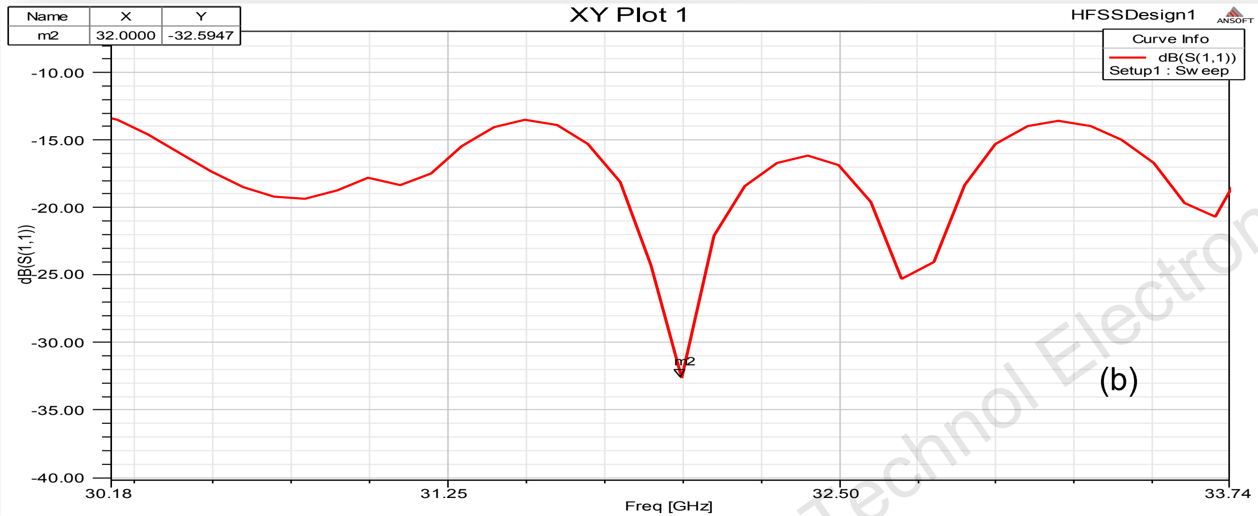
Resonant frequency(GHz)	12	14	37	39
Re(η)	2.85	- 1.6035	- 0.0052	- 0.441
Re(ε)	- 0.0942	- 0.1534	- 0.1045	0.0579
Re(μ)	0.0262	0.032	- 0.0873	- 0.0656



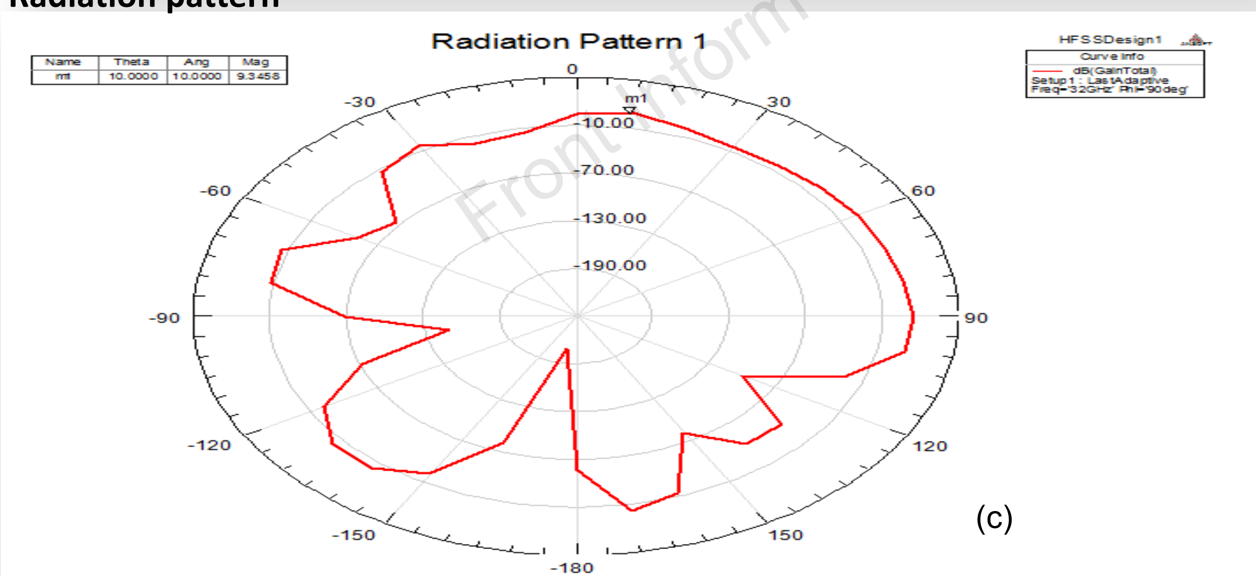
Permeability Vs. Frequency

SIMULATION RESULTS

Return loss.



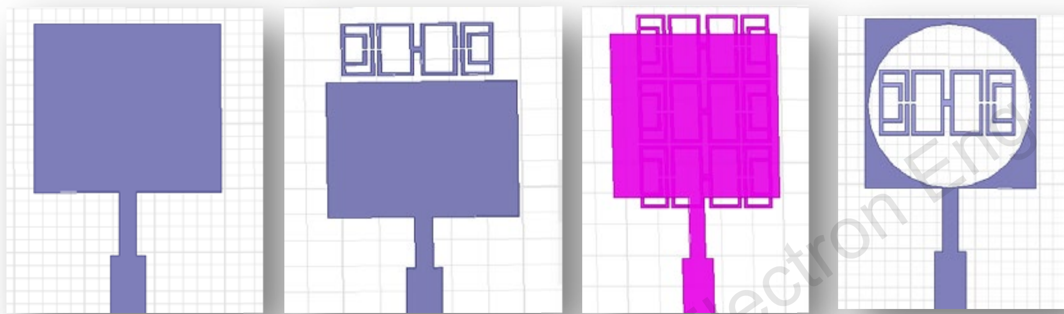
Radiation pattern



Bandwidth is 10 GHz.
Peak gain is 9.7dB
Peak directivity is 12.97 dB

ulation results for RMPA:(a) Return loss. (b) Radiation pattern in H plane of RMPA. (c) Real and imaginary parts of impedance vs. freque

Proposed antenna configurations



(a) (b) (c) (d)

Proposed antenna configurations: (a) Patch antenna, (b) metamaterial placed at a coupling distance of 0.5 mm from top of the patch in the middle of the substrate, (c) metamaterial array 3X1 formed with 0.5 mm gap between each, and (d) patch antenna with lessened active area.

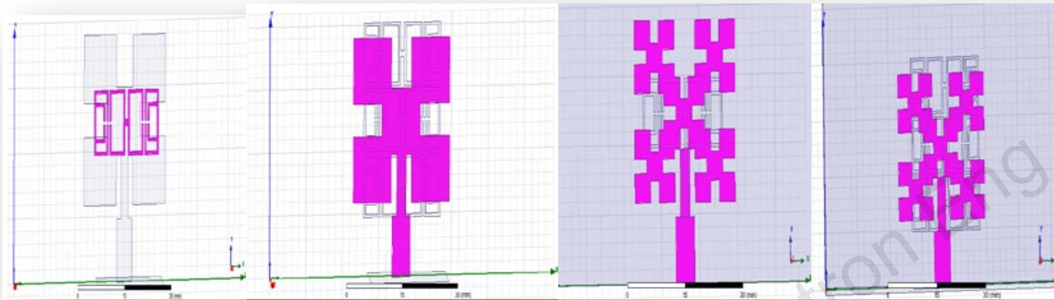
Configurations in figures	Gain (dB)	Directivity (dB)	Radiation efficiency(%)	Bandwidth (GHz)	Return loss (dB)	Active Area (mm^2)	Miniaturization (%)
(a)	9.7	12.97	73	10	32.59	694.3	--
(b)	10	10.4	97.4	16.34	23.28	694.3	71
(c)	9.7	9.4	99.5	91	39.19	694.3	78
(d)	8.7	7.4	100	77	30.12	241.9	71

maximum radiation efficiency

ultra-wide band

maximum miniaturization

Fractal antenna



10.5 mm x 10.5 mm

a) b) c) d)

Fractal metamaterial antenna

Configurations In figures	Gain (dB)	Directivity (dB)	Radiation Efficiency (%)	Bandwidth (GHz)	Return loss (dB)	Miniaturization
(a)	10.23	10.26	99.28	16.59	26.32	7%
(b)	8.9	8.9	98.9	20	28.8	--
(c)	7	7	98	41.4	31	1/21 at 1.5 GHz
(d)	7	7	97	34	20	1/5 at 6 GHz

ultra-wide band

maximum miniaturization

CONCLUSION

	Resonant frequency f0 (GHz)	Bandwidth (GHz)	Miniaturization (%)	Gain (dB)
Patch	11.4	0.8	-	1.4
Active	4.8 and 8.6	5.2	57	2.5
Fractal	1.9 and 4.03	0.26 and 3.2	(1/6)th	4.8

Thus, "fabricated and simulated antennas" helps in achieving miniaturization and bandwidth enhancement which is in coherence with the proposed antenna configurations