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

Key words: Ultra-wideband; Antenna; Metamaterial

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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.

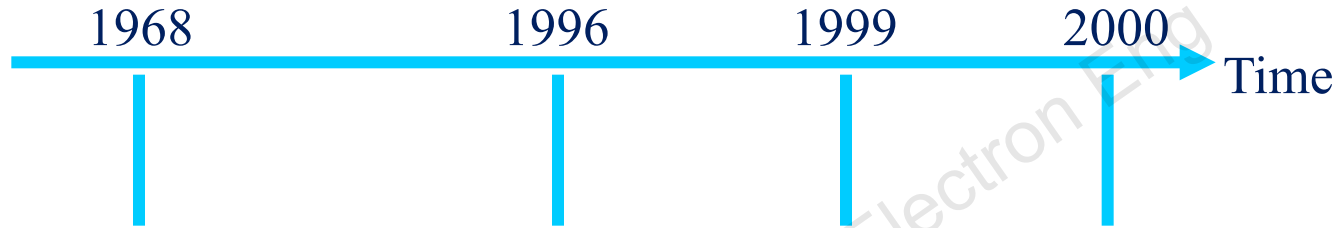
From the analysis of various shapes of metamaterials, an approximate design methodology for size reduction and bandwidth enhancement has been attempted.

NEGATIVE INDEX METAMATERIALS

Main idea

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

Timeline:



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



$$\epsilon_m < 0$$

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

$$\epsilon_{\text{eff}} = 1 - \frac{\omega_p^2}{\omega^2}$$

ω_p : controllable plasma frequency

Magnetic Response



Split Ring Resonator (SRR)

Collection of SRR forms effective magnetic medium.

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

Γ : dissipation factor F : fractional factor



[V. G. Veselago. The electrodynamics of substances with simultaneously negative values of ϵ and μ . Soviet Physics-Uspekh, 10(4):509–514, January-February 1968.]

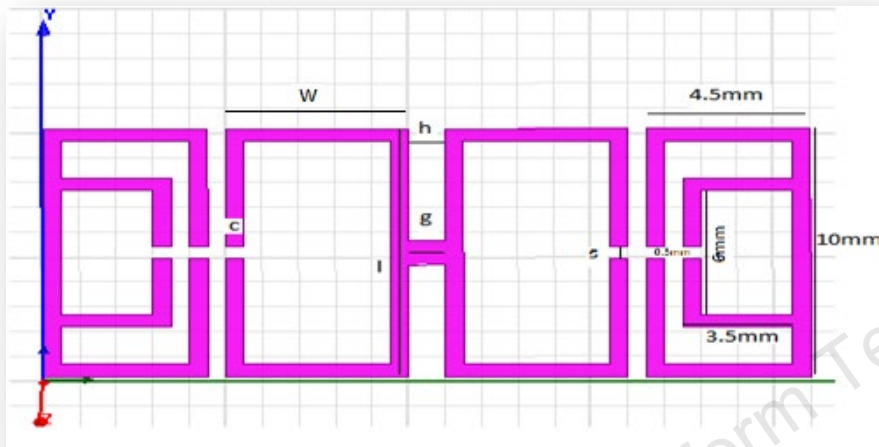
[J. B. Pendry, A. J. Holden, W. J. Stewart, and I. Youngs, "Extremely low frequency plasmons in metallic micro structures," Phys. Rev. Lett., vol. 76, pp. 4773–4776, 1996.]

[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

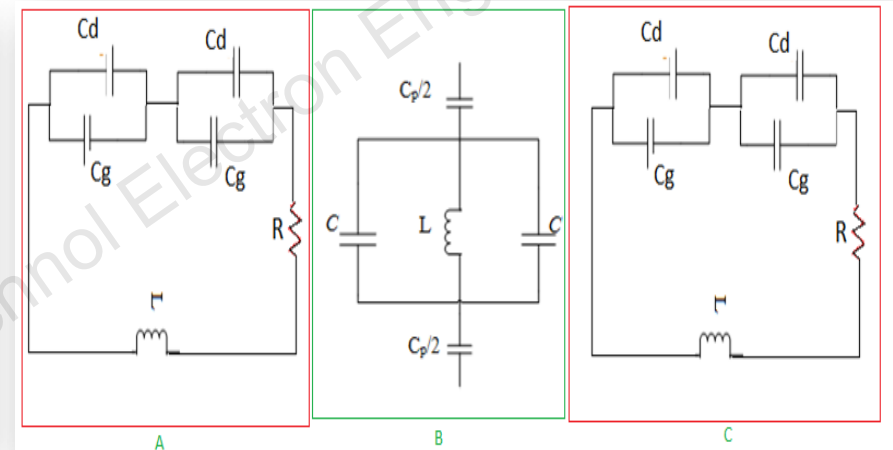
It is composed of modified H-shaped resonating copper conductors placed between two modified SRR structures.



(a) Schematic view

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

(c) Design parameters



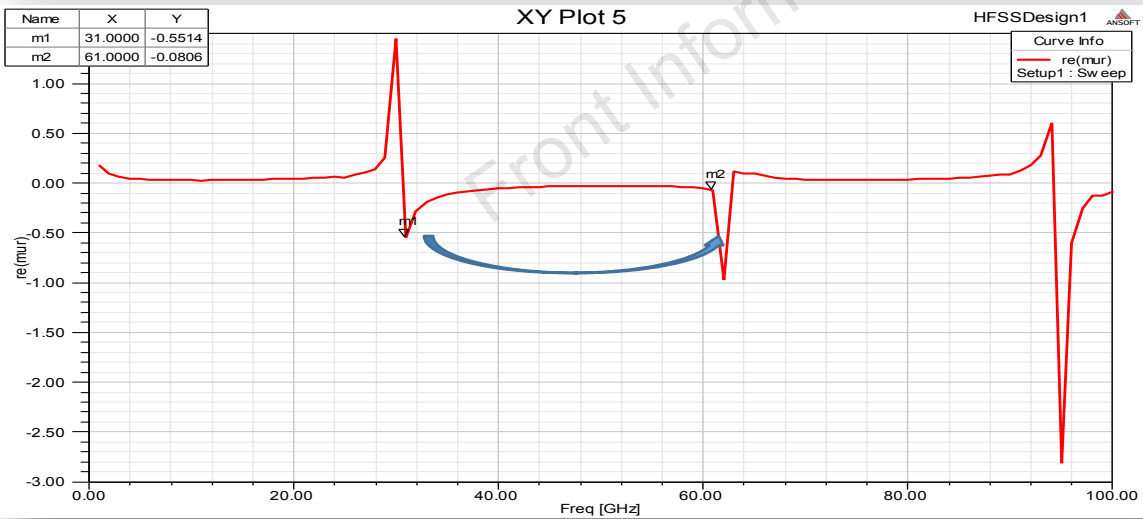
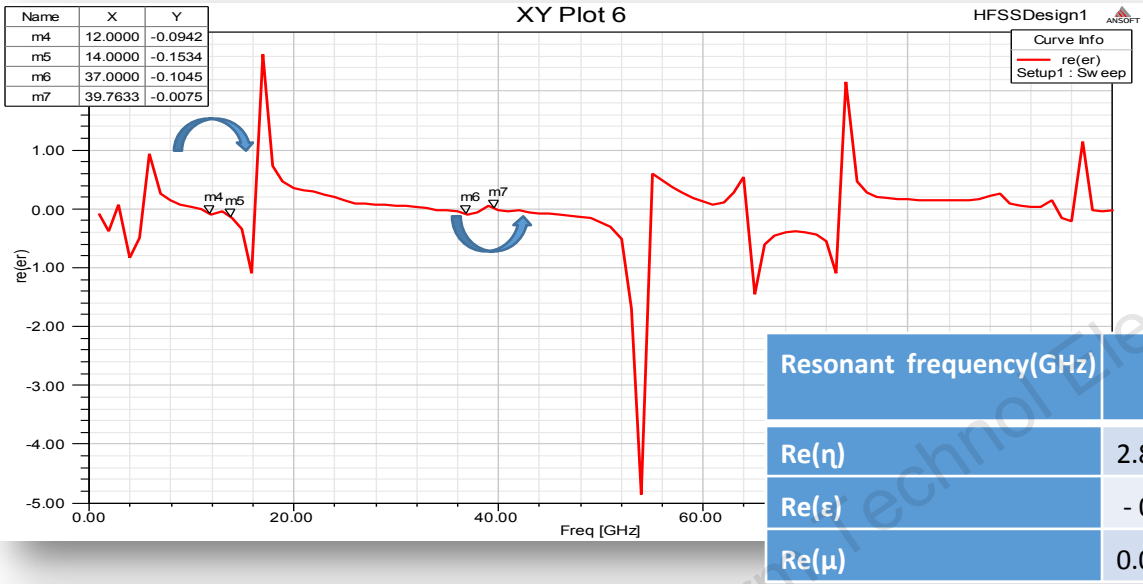
(b) Equivalent circuit

$$C = \epsilon_0 \epsilon_r \frac{A}{d} \quad L = \mu_0 t \left[\frac{2c}{2w+h} + \frac{\sqrt{(2w+h)^2 + l^2}}{c} \right]$$

$$C_p = \epsilon_0 \left[\frac{2w+h}{\pi} \ln \frac{2c}{a-l} \right]$$

6% error

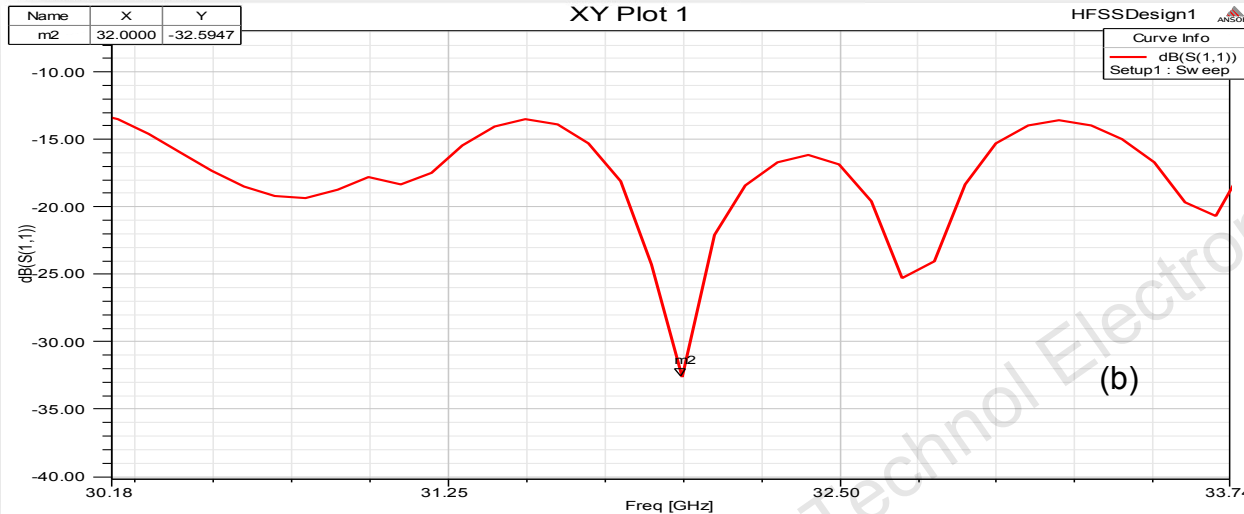
Simulation results



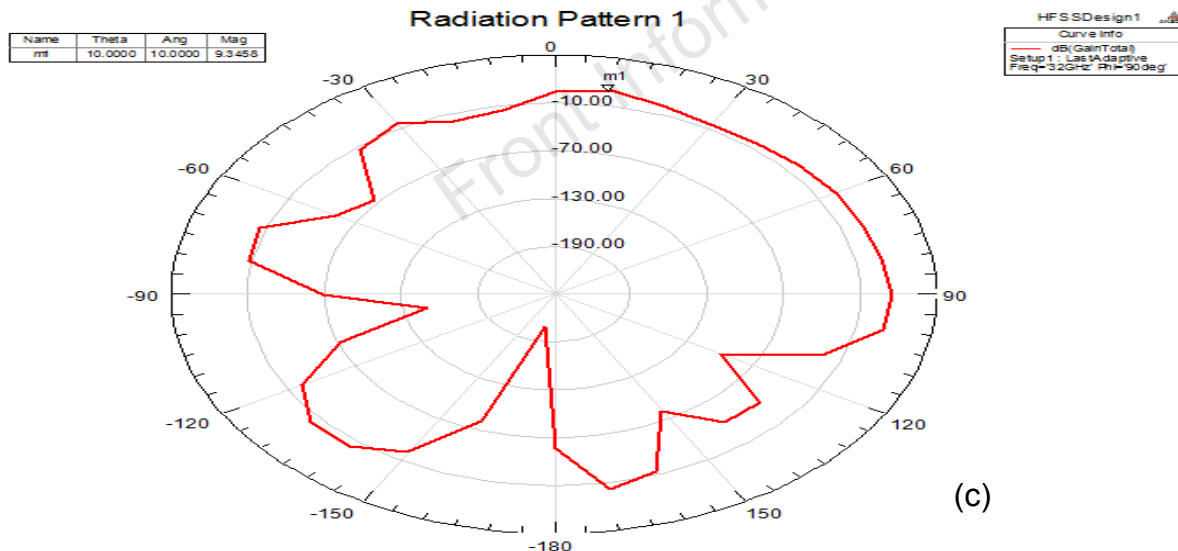
Permeability Vs. Frequency

SIMULATION RESULTS

Return loss.

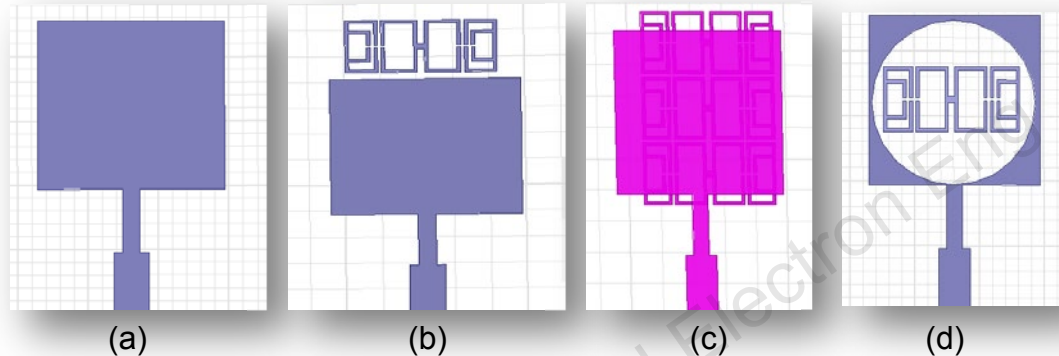


Radiation pattern



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

Proposed antenna configurations



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.

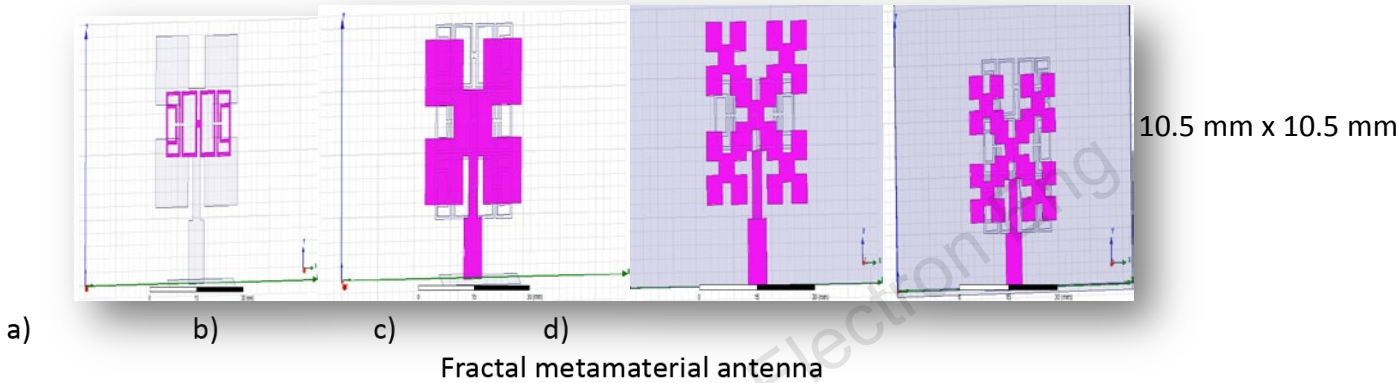
Configurations in figures	Gain (dB)	Directivity (dB)	Radiation efficiency(%)	Bandwidth (GHz)	Return loss (dB)	Active Area (mm ²)	Miniaturization (%)
(a)	9.7	12.97	73	10	32.59	694.3	--
(b)	10	10.4	97.4	16.34	23.28	694.3	71
(c)	9.7	9.4	99.5	91	39.19	694.3	78
(d)	8.7	7.4	100	77	30.12	241.9	71

maximum radiation efficiency

ultra-wide band

maximum miniaturization

Fractal antenna



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