Metamaterial Integrated-Patch Antenna for Improved Performance

Abstract: In recent years, metamaterials have emerged as a promising technology for enhancing the performance of various electromagnetic devices, including antennas. In this paper, we propose a metamaterial-integrated patch antenna design aimed at improving its performance. The proposed antenna is designed to operate in the frequency between 7 to 12 GHz. The design is simulated using CST microwave studio and optimised to achieve maximum performance.

***Keywords*: Metamaterial, NIM, DNG, MNZ, ENZ, CPW feeding, Microstrip feeding**

I. INTRODUCTION

Research indicates that the use of wearable antennas in wireless body area applications (WBAN) has quickly expanded recently. This article introduces a low-profile antenna incorporating metamaterial for WBAN applications. But a significant problem is creating to design an effective wideband small-size antenna for certain applications. Narrow bandwidth is typically a downside of microstrip patch antennas. Patch antennas are low profile, lightweight, and economical. Their limited bandwidth is their biggest flaw, though. Researchers used a variety of strategies to increase bandwidth in order to solve this issue[1]-[6], including expanding substrate size, making slots[10], employing magneto-dielectric substrates, adding parasitic patches[7]-[9], and using an artificial magnetic ground plane.

In this approach, A new material known as metamaterial has just been introduced. These are artificially engineered composite materials that exhibit unique characteristics which are not present in natural materials. They are refered as metamaterials.

In 1967, Russian physicist Viktor Veselago presented a theoretical study in which he proposed the possibility of materials with negative values of both permittivity and permeability. He showed that such materials would exhibit unique electromagnetic properties, including negative refraction, backward wave propagation, and a reversed Doppler effect.

In 1999, Rodger M.Walser and his team at the University of Texas at Austin published a paper titled "Experimental Verification of Negative Refraction" in which they demonstrated the first experimental verification of negative refractive index in a metamaterial. They achieved this by creating a metamaterial structure consisting of an array of split-ring resonators and wires on a printed circuit board substrate, which exhibited negative refractive index at microwave frequencies.

This work was significant because it provided experimental evidence for the concept of negative refractive index that had been proposed by Viktor Veselago in 1967.

In addition to this paper, Walser and his team made other contributions to the development of metamaterials including the introduction of the term "metamaterial" .

In 1999, Sir John Pendry, a theoretical physicist at Imperial College London, published a paper titled "Negative Refraction Makes a Perfect Lens" in which he proposed the idea of using metamaterials with negative refractive index to create a "perfect lens" that could overcome the diffraction limit of conventional lenses.

Basic Properties of Metamaterials:

Consider maxwells first order differential equations,

$$\nabla \times E = -j\omega\mu\,(H) \text{----------}(1)$$

$$\nabla \times H = -j\omega\mu\, E \text{ ------------}(2)$$

Where ω is the angular frequency

For plane-wave electric and magnetic fields like

$$E=E0\ e^{(-jk.r+j\omega t)} \text{-----------------------}(3)$$

$$H=H0\ e^{(-jk.r+j\omega t)} \text{----------------------}(4)$$

$$K \times E=\omega\mu H \text{------------------}(5)$$

$$K \times H=-\omega\varepsilon E \text{------------------}(6)$$

For simultaneous positive values of ε and μ, the vectors E, H and k make a right-handed orthogonal system there will be forward wave propagation in this medium.

For simultaneous negative values of ε and μ, Equations (5) and (6) can be rewritten as

$K \times E=-\omega|\mu|H$

$K \times H=\omega|\varepsilon|E$

And the vectors E, H and k make a left-handed orthogonal system.

Energy flow is determined by the real part of pointing vector.

$S=1/2\ (E\times H^*)$

For simultaneous change of sign of permittivity and permeability, the direction of energy flow is not Affected, therefore, the group velocity will be positive for both left-handed and right-handed system. Refractive index is given as:

$n=+/-(\sqrt{\varepsilon\mu})$

phase velocity is given as

$$vp=c/n$$

II. ANTENNA DESIGNING

Microstrip feed without metamaterial

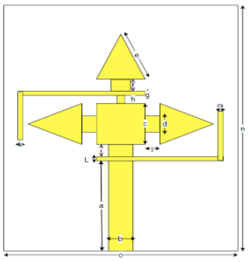

Fig 1

PARAMETER LIST:

S.no	Parameter	Length(mm)
1.	a	6.3
2.	b	1
3.	c	2.5
4.	d	1
5.	e	2.6
6.	f	0.95
7.	g	0.3
8.	h	0.4
9.	i	
10.	j	0.85
11.	k	0.4
12.	L	0.3
13.	m	0.4
14.	n	12
15.	o	15

Table 1

Figure 1 shows the proposed compact antenna's geometry. It is built on a FR-4 and Rogers RO3003 substrate with a permittivity of 4.3 and 3 with a thickness of 1.5mm. To achieve a 50Ω characteristic impedance, the microstrip feed line's width is fixed at 1mm. One parameter at a time is changed while the other ones are fixed to investigate the suggested antenna. The CST programme is used to analyse the antenna in order to fully comprehend how its structure behaves and identify the ideal parameters. Table 1 displays the proposed antenna's physical parameters.

CPW feed without metamaterial

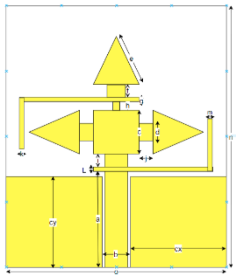

Fig 2

S.no	parameter	Length(mm)
1.	cy	
2.	cx	

Table 2

Figure 2 shows the proposed compact antenna's geometry. It is built on a FR-4 and Rogers RO3003 substrate with a permittivity of 4.3 and 3 with a thickness of 1.5mm. To achieve a 50Ω characteristic impedance, the microstrip feed line's width is fixed at 1mm. One parameter at a time is changed while the other ones are fixed to investigate the suggested antenna. The CST programme is used to analyse the antenna in order to fully comprehend how its structure behaves and identify the ideal parameters. Table 1 displays the proposed antenna's physical parameters.

Microstrip feed antenna with metamaterial

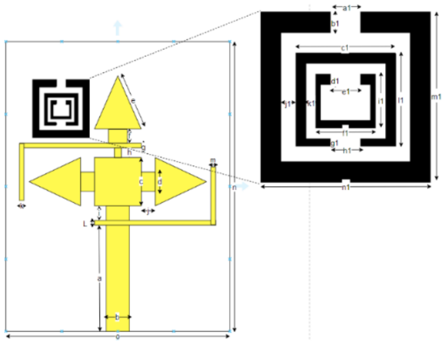

Fig 3

Figure 2 shows the proposed compact antenna's geometry. It is built on a FR-4 and Rogers RO3003 substrate with a permittivity of 4.3 and 3 with a thickness of 1.5mm. To achieve a 50Ω characteristic impedance, the microstrip feed line's width is fixed at 1mm. One parameter at a time is changed while the other ones are fixed to investigate the suggested antenna. The CST programme is used to analyse the antenna in order to fully comprehend how its structure behaves and identify the ideal parameters. Table 1 displays the proposed antenna's physical parameters.

CPW feed antenna with metamaterial

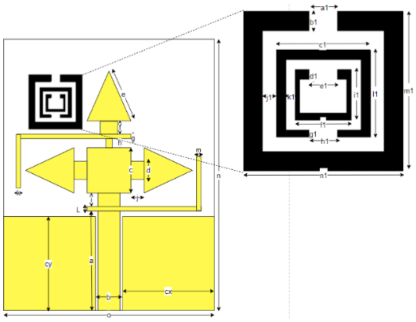

Fig 4

PARAMETER LIST:

S.no	Parameter	Length(mm)
1.	a1	
2.	b1	
3.	c1	
4.	d1	
5.	e1	
6.	f1	
7.	g1	
8.	h1	
9.	i1	
10.	j1	
11.	k1	
12.	l1	
13.	m1	
14.	n1	

Table 2

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III. ANALYSIS OF PROPOSED ANTENNA

Analysis of microstrip feed antenna without metamaterial

1. FR-4 as substrate material

Figure 5 shows s-parameters of proposed antenna which uses FR-4 as substrate without integrating metamaterial into it.

Operating frequency of this antenna is from 7 to 12 GHz. |S1,1| parameter of this Antenna is -47.148dB at resonating frequency of 8.4497GHz. From figure 5 we can say that proposed antenna has a bandwidth of 355MHz i.e., from 8.28GHz to 8.635GHz which is having |S1,1| < -10.

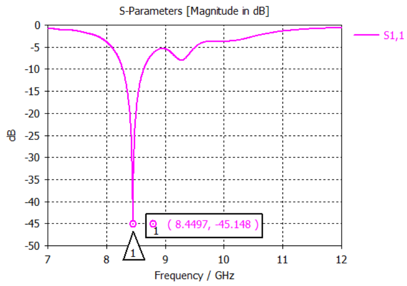

Fig 5

Figure 6 represents VSWR of proposed antenna. VSWR of 1.010 indicates that the antenna is very well matched to the transmission line or the source impedance, with a very small amount of reflected power. Antenna having VSWR< 2 would indicate a perfect match.

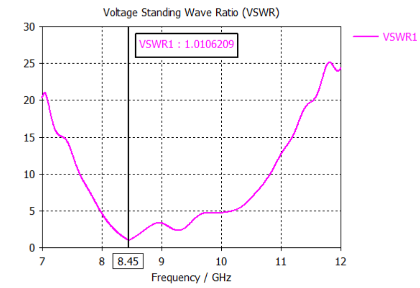

Fig 6