Design of a microstrip metamaterial for C-band Radar absorber

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Abstract. Electromagnetic wave absorber has an important role in radar technology used for military as well as for civilian application. There are many electromagnetic wave absorbing technologies used in current radar technology, one of which is an absorber based on metamaterial. In this paper, design of a microstrip metamaterial for C-band radar absorber will be discussed. The metamaterial absorbers on the C-band range is designed on microstrip material having a thickness 4.8 mm and dielectric constant 2.17. There are several techniques can be implemented to broaden the working frequency, which are increasing substrate thickness, decreasing dielectric constant and patch modification. In this work, the simulation method is employed for optimizing the design and achieving good electromagnetic wave absorption at the C-band working frequency. Simulated result show the microstrip metamaterial design has broadband absorption lower than -10 dB ranging from 4.3 GHz to 7.1 GHz. Based on the characteristics, this design can be realized as radar absorber at C-band frequency.

1. Introduction
The radar absorber is an advanced technology that can be applied for many purposes. In developing the radar component and antenna, the characterization of component should be performed in an anechoic chamber [1-4]. In addition, stealth technology is a process of absorbing RADAR waves by a material. This technology has become a modern military innovation today, for monitoring and anticipating the disruption of border security [5]. Applications of stealth technology are developed in two ways, which are the reflection of RADAR waves in the other direction and the absorption of waves. In reflection technology, military equipment is designed to reflect RADAR waves in the other direction, but the development of this method requires a large budget. Meanwhile, absorption technology is carried out by coating the surface of the ship using a material that is able to absorb RADAR waves, which are absorbent waves.

The absorption technology of electromagnetic waves has given created to a new material the RADAR Absorber Material (RAM). This material has the characteristic of reducing reflections or absorbing electromagnetic waves. The absorber material is influenced by impedance matching of the material with electromagnetic waves through the mechanism of the resonance frequency which is formulated with a reflection coefficient (dB). In previous works, several low cost radar absorbers have been developed based on natural carbon material [6-7]. However, the carbon based is bulky and less flexible in applications. Another way to absorb RADAR waves is to use metamaterials on microstrips.
Metamaterial comes from the Greek word μετά, which means "outside" is a material that is engineered to have properties not found in nature [8]. Metamaterial is a medium / material designed to have the characteristics of permeability and negative permittivity, these characteristics make metamaterials can be used to absorb electromagnetic waves. Metamaterials have two types, volumetric (3D) and planar (2D / 1D). The first type has characteristics characterized by the field theory, while the second is modeled by transmission line theory. Microstrip uses a planar metamaterial because it has a flat shape.

Radar Cross-Section (RCS) is a measure of how much an object is detected by radar. The radar cross section of the target is an area that holds a certain amount of energy which when the radar is fired in all directions will produce an echo from the target or in other terms [9]. Larger RCS indicate that objects are easier to detect. Reduction of RCS can be achieved by integrating RADAR Absorbent Materials (RAMs) or by modifying the target geometry to dissipate reflected waves or both [10].

The absorption of electromagnetic waves can be done by reducing RADAR Cross Section [11]. The type of electromagnetic wave absorption is divided into 2 (two) namely material engineering and geometry engineering (Shape). Material engineering is when making a material by adding several elements of its fixed structure. While engineering geometry of its manufacture should pay attention to particle shape, thickness, electric field and magnetic field.

The development of metamaterial absorber with broadband quality can generally work on the X-band working point, because the characteristics of the materials in the market are very supportive for X-bands such as large dielectric constants and thin thickness. On the other hand, the C-band frequency is widely used for airborne and space borne. Now, the metamaterial absorber working on a C-band frequency with a very large 10-dB reflectivity is very small [11-13]. The three studies that have been carried out only produce small bandwidth and not broadband quality. So the development of metamaterial absorber for C-band with reflectivity of -10 dB with broadband quality is still very rare.

Electromagnetic waves absorbed by metamaterials have different frequencies. This frequency difference depends on the resonant frequency of the microstrip metamaterial design. The magnitude of absorption in metamaterial can be calculated using the following equation [12]:

\[ A(\omega) = 1 - R(\omega) - T(\omega) \] (1)

With A is absorption, R is reflectivity (S11) and T is transmitter (S21) on a metamaterial absorber.

Creating microstrip metamaterial can be done by design and simulation in order to get the expected research result. In designing and simulating of metematerial done using CST Studio Suite software.

2. Absorber Design and Analysis
In designing the design of the metamaterial microstrip there are several stages. First designing the RLC circuit, there are several components in the RLC circuit such as R1, L1, L2, C1, Cgap and Zd. The shape of the RLC circuit can be seen in Figure 1.

![Figure 1. Schematic of RLC circuit](image-url)
As can be seen in Figure 1, the L1, C1 and L2 are arranged in parallel. This parallel circuit is connected with Cgab and R1 which form the series series. This RLC sequence is connected in parallel with Zd. From this sequence, a metamaterial design was made. In the L2 and L2 metamaterial designs are patches, C1 is the capacitance between L1 and L2, Cgab is the capacitance between cell units, R is the resistance of the patch and Zd is the dielectric impedance. In general, the amount of resistance on a microstrip is 50 ohms. The metamaterial design consists of ground, substrate and 2 patches. Substrate has dielectric constant 2.17, loss tangent 0.0005 with thickness 4.8 mm. The shape of the absorber metamaterial design can be seen in Figure 2.

![Figure 2. Design of the metamaterial](image)

where \(a\) is the patch length, \(r\) is the middle distance to the edge of the patch, \(m\) is the distance of the patch edge to the edge of the substrate, \(o\) is the length of the fractal square, \(t\) is the thickness of the patch, and \(d\) is the thickness of the substrate. In this research, there are variations of microstrip metamaterial parameter size in the form of simulation.

### Table 1. Dimension of the metamaterial absorber design in mm

|   | \(a\) | \(m\) | \(r\) | \(o\) | \(\varepsilon\) | \(d\) | \(t\) |
|---|---|---|---|---|---|---|---|
|   | 5.6 | 0.5 | 0.5 | 3.3 | 2.17 | 4.8 | 0.035 |

3. **Result and Discussion**

Data characterization results in this study are using CST Studio to simulate the design of metamaterial and identify reflectivity. Simulation of microstrip metamaterial uses cell boundary condition unit. This simulation uses the infinite array element method. In this simulation the frequency is used in the range 1-8 GHz. The result of this simulation is the amount of electromagnetic energy on port S11. Electromagnetic energy graph can be seen in Figure 3.
From Figure 3 it can be seen that the microstrip metamaterial works in the frequency range from 4.15 to 7.9 GHz under -10 dB. The influence of variable microstrip metamaterial can be seen in Figure 4-7.

**Figure 3.** Microstrip metamaterial simulation results

**Figure 4.** The reflection coefficient as function of frequency for patch distance variation

**Figure 5.** The reflection coefficient as function of frequency for large patch variations
Figure 6. The reflection coefficient as function of frequency for variation of unit cell distance

Figure 7. The reflection coefficient as function of frequency for variation of dielectric constant

From Figure 4 to Figure 7 can be seen simulating some microstrip variable variation metamaterial, it can be increased coefficient of reflection of electromagnetic waves will decrease the operating frequency range of metamaterial microstrip, otherwise widen the working frequency range will reduce the coefficient of reflection of electromagnetic waves.

In the simulation data analysis results obtained varying absorption. The absorption of electromagnetic waves depends heavily on the magnitude of the reflection of the microstrip metamaterial. The wave absorption graph of the metamaterial can be seen in Figure 8.
From Figure 8 can be seen the absorption of electromagnetic waves began to increase at a frequency of 2.5 GHz and continue to rise. The amount of absorption began to fall at a frequency of 4.5 GHz and rise again at a frequency of 5.4 GHz. Maximum absorption occurs at a frequency of 4.45 GHz to 99.9%.

4. Conclusion
Analyzing absorption data is done with several stages. The first stage enters the reflection data from both simulation and measurement into Microsoft Excel applications. The reflection data on S11 port is processed to obtain a large reflectivity. Furthermore, the reflectivity is processed using formula 11 to produce absorption on microstrip metamaterial. From the simulation of several variations of microstrip metamaterial variables can be seen increasing the absorption power of electromagnetic waves will reduce the working frequency of microstrip metamaterial, otherwise widening the working frequency will reduce the absorption of electromagnetic waves.

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References
[1] Hussein M, Yohandri, Sri Sumantyo JT, and Yahia A 2013 A low sidelobe level of circularly polarized microstrip array antenna for CP-SAR sensor. Journal of Electromagnetic Waves and Applications 27(15): 1931-1941
[2] Baharuddin MZ, Izumi Y, Sri Sumantyo JT, and Yohandri 2016 Side-Lobe Reduced, Circularly Polarized Patch Array Antenna for Synthetic Aperture Radar Imaging. IEICE Trans. Electronic E99.C (10) : 1174–1181
[3] Yohandri, Asrizal, and Sri Sumantyo JT 2016 Design of tilted beam circularly polarized antenna for CP-SAR sensor onboard UAV Proc. Int. Symposium on Antennas and Propagation (ISAP) (Okinawa Japan) pp 658–659
[4] Yohandri, Sri Sumantyo JT and Kuze H 2011 Circularly polarized array antennas for synthetic aperture radar. Proc. Progress in Electromagnetics Research Symposium (Souzhou China) pp 1244–1247
[5] Fadhallah Esa Ghanim. 2012. Prototype Material Penyerap Gelombang RADAR Dari Komposit Polimer Chitosan-Polvinil Alcohol. Bandung: Institut Teknologi Bandung.
[6] Yohandri, Rianto D, and Putra A 2017 Study of single layer Radar Absorber Material (RAM) based on coconut shell activated carbon. Proc. Progress in Electromagnetics Research Symposium (Singapore) pp 1536 – 1539
[7] Satria N, Yohandri and Putra A 2017, Synthesis and characterization of cocoa pods waste carbon
for Radar Absorber Material. *Proc. Progress in Electromagnetics Research Symposium* (Singapore) pp 1532 – 1535

[8] Kshetrimayum, RS. 2004. A Brief Introduction to Metamaterials. Potensi IEEE. Hal 1.

[9] Skolnik, Merrill Ivan. 1981. *Introduction to RADAR systems* (Second edition). McGRAW-HILL BOOK COMPANY. USA.

[10] Modi, Anuj Y., et al. 2016. Novel Design of Ultra-Broadband RADAR Cross Section Reduction Surfaces using Artificial Magnetic Conductors. *IEEE Transactions On Antennas And Propagation*.

[11] Zhang, Hao, et al. 2014. A Novel Dual-Band Metamaterial Absorber and Its Application for Microstrip Antenna. *Electromagnetics Research Letters*, Vol. 44, 35-41.

[12] Jamil, Saeid, Mohammad N. Azarmanesh and Davoud Zarifi. 2014. Design and Characterization of a Dual-Band Metamaterial Absorber Based on Destructive Interferences. *Progress In Electromagnetics Research C*, Vol. 47 95-101.

[13] Susanto, Heri Agus, Eko Setijadi and Puji Handayani. 2016. Simulation Design of Triple Band Metamaterial Absorber for RADAR Cross Section Reduction. *IEEE COMNETSAT*.