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Milli Savunma Üniversitesi
Deniz Harp Okulu Dekanlığı 34940
Tuzla/İstanbul/Türkiye

Phone/Telefon : +90 216 395 26 30
E-mail/E-posta : *jnse@dho.edu.tr*
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TURKISH NAVAL ACADEMY
JOURNAL OF NAVAL SCIENCES AND ENGINEERING

MİLLİ SAVUNMA ÜNİVERSİTESİ
DENİZ HARP OKULU DEKANLIĞI
DENİZ BİLİMLERİ VE MÜHENDİSLİĞİ DERGİSİ

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Prof. Dr. Cemalettin ŞAHİN

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EDITORIAL

FOREWORD

As we conclude another year of outstanding contributions to the field of engineering and science, we are pleased to present the final issue of the Journal of Naval Sciences and Engineering for 2023. In this issue, we are proud to feature three research articles that reflect the diversity and depth of engineering research, as well as a timely book review that offers insights into a recently published work.

Our commitment to providing a platform for a wide array of engineering disciplines is evident in the selection of articles for this issue. Each article showcases the innovative thinking and technical prowess that continue to drive our field forward. From exploring the hydrodynamics of marine propulsion systems to the development of advanced steganography algorithms for securing data, and the design and optimization of dual-band polarizers, these articles represent the cutting edge of engineering research. Additionally, the book review provides an in-depth analysis of the latest edition of a seminal work in electromagnetics, offering valuable perspectives for both academics and professionals.

I would like to extend my heartfelt gratitude to all the authors for their invaluable contributions and to our anonymous reviewers for their diligent efforts in maintaining the high standard of the journal. Your expertise and dedication are the backbone of our publication's success.

Looking ahead, we are excited to announce that our next issue is planned for publication in June 2024. We anticipate another collection of high-quality papers that will continue to enrich the body of knowledge in naval sciences and engineering, as well as other related fields of engineering.

As we bid farewell to 2023, I would like to express my sincere appreciation to our readers, contributors, and reviewers. May the upcoming year be filled with new discoveries, innovative research, and continued collaboration within our vibrant scientific community.

Fatih ERDEN, Ph.D.
Editor-in-Chief

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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

NUMERICAL INVESTIGATION OF THE HYDRODYNAMIC PERFORMANCE OF A PROPELLER CONVERTED FROM FPP TO CPP*

Ahmet YURTSEVEN*

Yildiz Technical University, Department of Naval Architecture and Marine Engineering, Istanbul, Turkey, ahmety@yildiz.edu.tr

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ABSTRACT

Present paper investigates the hydrodynamics of a Controllable Pitch Propeller (CPP) which is generated by geometrical modifications applied on a benchmark propeller designed as a fixed pitch propeller (FPP). The aim of the study is to examine the practical feasibility of converting a propeller model designed as a FPP to a new one operating with CPP principles. The flow around propeller models is solved via computational fluid dynamics and the results of the new generated model are presented in comparison with its parent geometry. The well-known KP505 propeller model is chosen as test case. The primary results show that the effect of the geometrical modifications on the propeller efficiency mainly depends on the propeller load and the blade pitch angle. The optimum efficiency point is determined as J=0.8, for the new design model. For the J values below this point, negative pitch angle changes improve the efficiency compared to FPP model. If the J exceeds the above mentioned value, positive pitch angle changes are needed to gain efficiency increase. The results led us to conclude that, it's possible to convert a FPP to a CPP, but the blade pitch angle should be carefully controlled, for efficient operation.

Keywords: *FPP to CPP, Fix-Pitch Propeller, Controllable Pitch Propeller, CFD, RANS*

Ahmet YURTSEVEN

FPP'DEN CPP'YE DÖNÜŞTÜRÜLEN BİR PERVANENİN HİDRODİNAMİK PERFORMANSININ SAYISAL İNCELENMESİ

ÖZ

Bu makale, sabit hatveli pervane (FPP) olarak tasarlanmış bir pervane üzerinde uygulanan geometrik modifikasyonlarla oluşturulan Kontrol Edilebilir Hatveli Pervanenin (CPP) hidrodinamiğini incelemektedir. Çalışmanın amacı, FPP olarak tasarlanmış bir pervane modelinin CPP prensipleriyle çalışan yeni bir pervaneye dönüştürülmesinin pratikte uygulanabilirliğini incelemektir. Pervane modelleri etrafındaki akış hesaplamalı akışkanlar dinamiği ile çözülmüş ve yeni oluşturulan modelin sonuçları ana geometrisi ile karşılaştırmalı olarak sunulmuştur. İyi bilinen KP505 pervane modeli test vakası olarak seçilmiştir. İlk sonuçlar, geometrik değişikliklerin pervane verimliliği üzerindeki etkisinin esas olarak pervane yüküne ve kanat hatve açısına bağlı olduğunu göstermektedir. Yeni tasarım modeli için optimum verimlilik noktası J=0.8 olarak belirlenmiştir. Bu noktanın altındaki J değerleri için, negatif hatve açısı değişiklikleri FPP modeline kıyasla verimliliği artırmaktadır. J değerinin yukarıda belirtilen değeri aşması durumunda, verimlilik artışı elde etmek için pozitif hatve açısı değişikliklerine ihtiyaç duyulmaktadır. Sonuçlar, bir FPP'yi CPP'ye dönüştürmenin mümkün olduğu, ancak verimli çalışma için kanat hatve açısının dikkatlice kontrol edilmesi gerektiği sonucuna varmamızı sağladı.

Anahtar Kelimeler: *FPP'den CPP'ye, Sabit hatveli Pervane, Kontrol edilebilir hatveli Pervane, HAD, RANS*

1. INTRODUCTION

Propulsion of commercial and military marine vessels often relies on various types of propellers, typically positioned at the stern of the ship. The key factors influencing the performance of propellers are referred to as propeller speed, propeller diameter, and ship speed. The effectiveness of propellers is determined by the thrust they generate, the torque they demand, and their efficiency, which is influenced by these two variables. In recent times, extensive research has been conducted to investigate the impacts of these parameters on propeller performance (Wang et al., 2022). It is known that the propeller speed, which is the most important performance-impacting parameter, is limited by the main propulsion system that produces the mechanical shaft work. This results in very different performance of the propellers at different ship speeds. Controllable pitch propellers (CPP) have emerged with the idea of changing the propeller pitch to improve hydrodynamic performance while keeping the main propulsion system output speed constant. The propeller pitch is determined by the speed of the vehicle and the propeller speed to achieve maximum efficiency. In order to improve the performance, it is aimed to change the propeller pitch at the request of the vehicle user during the cruise (Turnbull,1931). The propeller speed, which is a crucial factor influencing performance, is limited by the primary propulsion system responsible for generating mechanical shaft work. Consequently, propellers exhibit varying performance levels at different ship speeds. Controllable pitch propellers (CPP) have emerged as a solution, allowing for adjustments to the propeller pitch in order to enhance performance while maintaining a constant output speed from the main propulsion system. The propeller pitch is determined based on the vehicle's speed and the propeller speed required to achieve maximum efficiency. The objective is to enable changes in propeller pitch during the cruise, as desired by the vessel operator, with the aim of improving performance (Turnbull, 1931). The challenges associated with Controllable Pitch Propellers (CPP) have led to limited information regarding the performance of various pitch propellers in the Wageningen-B series propellers (FPP) databases. While there have been a few experimental investigations, research on CPP propellers has predominantly focused

on the application of Computational Fluid Dynamics (CFD) techniques. In a recent study by Ozturk et al. (2022), a systematic examination was conducted to analyze the impact of propeller pitch on the self-propulsion point in ships, utilizing the Wageningen-B series propeller database. Funeno et al. (2013) conducted a comprehensive investigation into the pitch and performance of Controllable Pitch Propellers (CPP) utilized in commercial ships. Their study encompassed both experimental and numerical analyses, covering a broad range of conditions. Notably, they observed disparities between the numerical and experimental datas, particularly at low advance coefficients and near the neutral pitch points. As a result, they recommended further research into the flow characteristics around the propeller, with specific emphasis on examining the neutral pitch points. Rhee H.S. and Joshi S. (2003) conducted a validation study where they compared experimental results of the DTMB P5168 model CPP test propeller with Computational Fluid Dynamics (CFD) methods. However, it's worth noting that while the study utilized a CPP propeller geometry, it did not account for the motion of the blades around their shaft axis. In a separate numerical investigation by Kolakoti et al. (2013), the interaction between the propeller body and CPP propellers was studied. Additionally, Xiong Y. et al. (2013) examined the impact of fin geometries added to the CPP propeller hub on propeller characteristics and pressure distributions on the blades under open water test conditions. Controllable Pitch Propellers (CPP) necessitate the implementation of specialized blade root designs that facilitate proper interaction with the propeller hub, enabling blade movement. However, compared to Fixed Pitch Propellers (FPP), CPPs require significantly more intricate designs. In a recent study conducted by Yurtseven A. and Aktay K. (2023), the researchers converted a three-blade FPP propeller into a CPP configuration and examined the torques exerted on the blade shafts during blade pitch movements.

In this study, a test propeller designed with a fixed pitch, which is not common in the literature, has been geometrically updated and made usable for CPP purposes. The hydrodynamic performance of this mutant propeller is analyzed and compared with its FPP parent.

2. METHOD

2.1. Governing Equations

The study was solved in a computer environment using computational fluid dynamics (CFD) methods. The flow around the propeller is modeled as a 3-dimensional, time-dependent, incompressible and turbulent flow.

The governing equations used to model this flow are the continuity equation and the Reynolds-Averaged Navier Stokes (RANS) equations for three-dimensional, incompressible flow. The time-dependent continuity equation is given in equation 1.

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{1}$$

The momentum conservation equation is given in equations 2 and 3.

$$\rho\left(\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_i}\right) = -\frac{\partial P}{\partial x_i} + \frac{\partial \tau}{\partial x_j} - \frac{\partial\left(\overline{\rho u_i' u_j'}\right)}{\partial x_j} \tag{2}$$

where U_i is the mean velocity vector, u' is the turbulent velocity vector, $\left(\overline{\rho u_i' u_j'}\right)$ is the turbulence stress tensor, P is the mean pressure, ρ is the density and μ is the dynamic viscosity.

$$\tau = \tau_{ij} = \mu\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) \tag{3}$$

where τ_{ij} is the average molecular stress tensor.

In addition, the realizable $k-\varepsilon$ turbulence model was chosen to express the turbulence in the flow.

A commercial computational fluid dynamics code "Siemens Simcenter Star-CCM+" package program was used in the study. The governing equations are discretized using the finite volume method.

2.2. Geometry and Simulation Conditions

The test propeller geometry of KCS/KP 505, which was used as a fixed pitch propeller in the study, was converted from FPP propeller form to CPP propeller form by computer-aided design improvements. The FPP versions of this propeller have been used in a number of studies in the literature, especially recently in the field of hydrodynamics and cavitation (Lungo, A., 2018; Farkas et al.,2020). The propeller properties for the base propellers are given in Table 1.

Table 1. *KCS/KP 505 Propeller specifications*

D (m)	0.250
Z	5
Blade Section	NACA66 a=0.8
Rotation direction	Right

The converted CPP version of the FPP KCS/KP 505 propeller chosen as the test propeller is shown in Figure 1.

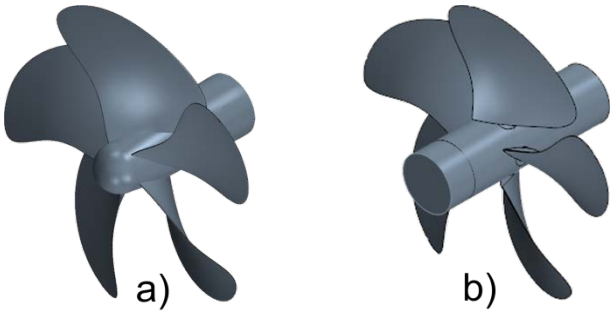

Figure 1. *a) FPP-KCS/KP 505, b) CPP-KCS/KP 505 CAD Geometries*

When the figure is examined, the development was applied by cutting the blades of the FPP propeller from the root region where they are connected to the main drive shaft and reassembling them with the help of shafts that will allow them to rotate around their own axis perpendicular to the main drive shaft. Thus, the blades are able to move around their own axis.

The idea behind the operation of CPP propellers is to change the pitch angles depending on the change in ship speed while keeping the propeller constant rotation. It is important to obtain the advance coefficient at which the propellers are most efficient. The advance coefficient depends on the ship speed and propeller revolution. Keeping the propeller rotation constant also ensures that the efficiency of the power generation and power transmission systems that drive it is kept high. Therefore, while keeping the propeller efficiency constant, it is necessary to change the propeller pitch to ensure that the efficiency is kept at the highest possible point with the change in ship speed. In this context, the direction of the pitch angle changed in the analysis is given as + (Pos) and - (Neg) as shown in Figure 2.

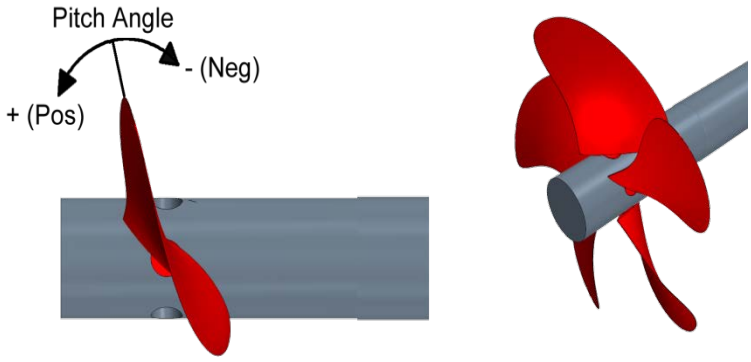

Figure 2. *Pitch angle directions for propeller blades*

2.3. Computational Domain and Boundary Condition

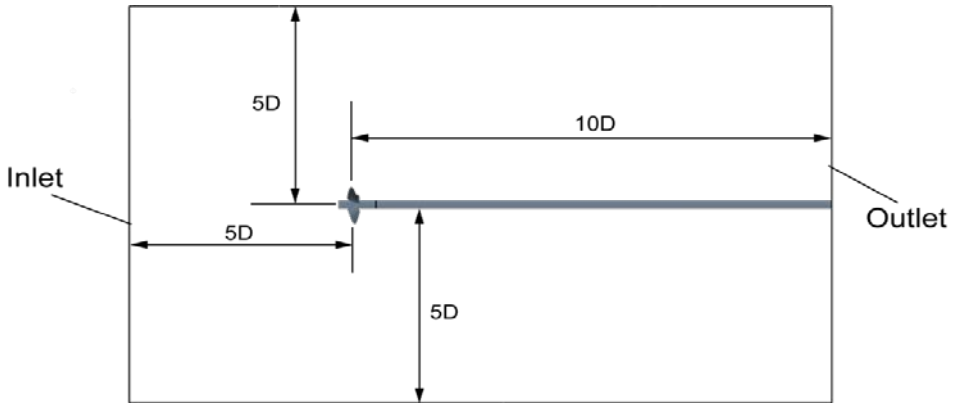

Figure 3. *Solution domain visualization*

In order to perform the flow analysis of the propellers, the flow domain shown in Figure 3 was created. The variable given as "D" in the figure refers to the propeller diameter. According to the direction of rotation of the propellers, the "Inlet" and "Outlet" boundary conditions in the solution domain are switched. Except for the propeller and shaft surfaces, all other external surfaces in the domain are used with the symmetry boundary condition.

Propeller open water test conditions were used in the study. In this context, the advance coefficient for the KCS/KP505-CPP propeller was taken as 0.2, 0.4, 0.6, 0.7, 0.8 and 0.9. The speed of the test propeller used in the study was taken as constant and 32 rps. Thus, different current speeds were used for each advance coefficient. These conditions are also considered suitable for the use of CPP propellers. Because the main purpose of using CPP propeller is to increase the propeller efficiency as much as possible at different ship speeds without changing the shaft speed at the highest point of the speed corrector transmission efficiencies by keeping the main engine speed constant. In the study, current input is used with uniform current input and current output is used with pressure output boundary condition.

It is known that two different rotational motions occur in controllable pitch propellers. The first of these motions is the basic rotational motion of the propeller around the main shaft axis. Apart from this basic rotational motion to which the propeller speed is applied, there is also the pitch motion of the blades around their own rotational shaft axes. In the analysis, the motion model called "Rigid Body Motion" combined with interfacial connections in the static domain was preferred for the basic rotational motion. For the blade pitch motion that will occur together with this motion, the motion called "Overset Motion" is used under superposition conditions. In the study, the time step was chosen to satisfy CFL<1 condition.

2.4. Solution Mesh Structure

In order to perform CFD analyses, solution domain decomposition was performed in accordance with the finite volume method. Thus, the solution mesh was obtained.

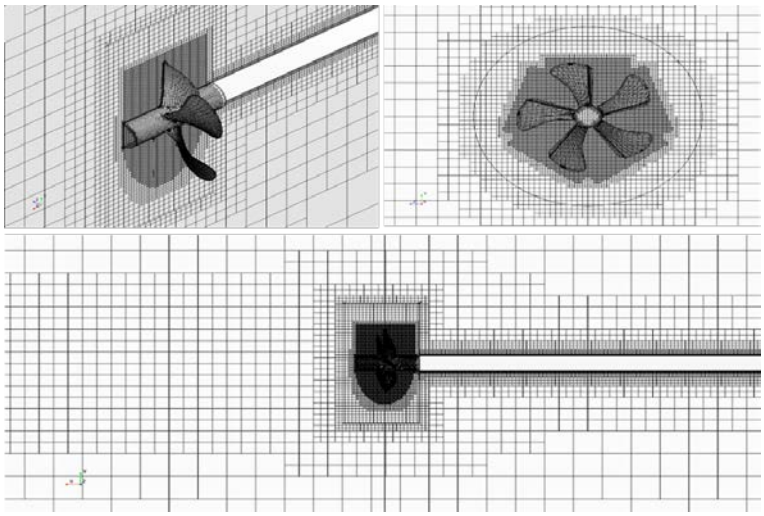

Figure 4. *Solution Mesh Image*

In the solution mesh, boundary layer mesh elements of the expanding type suitable for the boundary layer were preferred in order to estimate the wall velocities accurately, especially in the parts approaching the propeller surfaces. Hexahedral

solution elements were used in the solution mesh. The solution mesh structure used is shown in Figure 4.

The solution mesh was developed to keep the value of y+ (y+ = u*y/μ where u* is the reference velocity, y is the normal distance of the center of gravity of the cell nearest to the wall from the wall and μ is the kinematic viscosity) calculated with the first-row solution mesh width over the propeller between 30 and 150. The distribution of the wall y+ value in the numerical analysis for the controllable pitch version of the KCS/KP-505 propeller is shown in Figure 5.

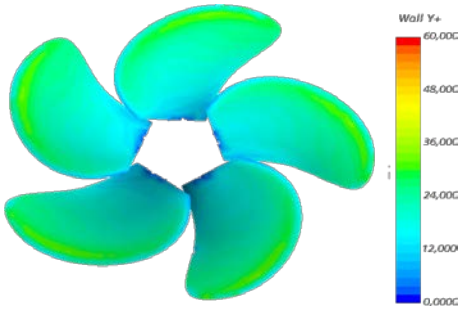

Figure 5. *KCS/KP 505-CPP (J=0.8) Wall Y+ Image*

The solution mesh independence and time step independence results for the analyses are given in Table 2.

Table 2. *Mesh dependency and Time step dependency Values (J=0.8)*

	Cell Count	**Trust [N]**
Finer	2618798	468,85
Fine	1302017	468,08
Medium	642223	466,35
Coarse	320829	464,24
Coarser	159309	461,60

	Timestep[s]	**Trust [N]**
Fine	0,0005	468,08
Medium	0,001	468,08
Coarse	0,002	465,34

When these results are examined, the "Fine" configuration was preferred as the solution mesh resolution and 0.001 s as the time step to be used in the analysis.

2.5. The Validation

In order to investigate the compatibility of the numerical model with the experimental data, six different advance coefficients (0.2, 0.4, 0.6, 0.7, 0.8, 0.9) were analyzed. The flow conditions and fluid properties used in the analysis are given in table 3.

Table 3. *Flow conditions and fluid properties*

J	0.2	0.4	0.6	0.7	0.8	0.9
V_A (m/s)	1.6	3.2	4.8	5.6	6.4	7.2
ρ (kg/m^3)	997.56	**μ (Pa.s)**	8.887E-4			

Figure 6 shows the experimental data (EFD) and numerical data (CFD) together.

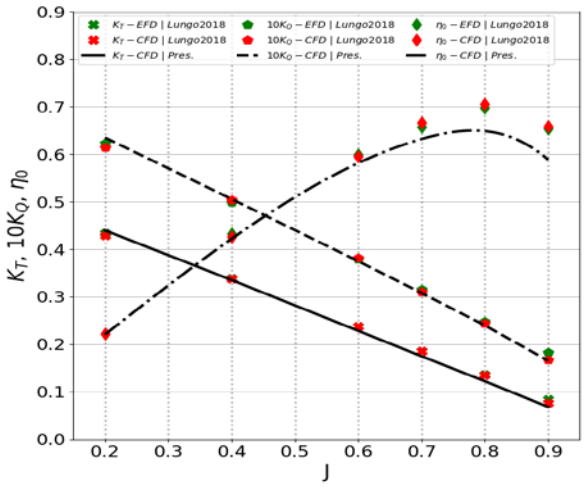

Figure 6. *Comparison of experimental and numerical data for the KCS/KP505 propeller (Lungu, A., 2018)*

When the figure is examined, it is seen that experimental studies and numerical studies give close results on an acceptable scale.

3. RESULTS

This section presents the results of the converted KCS/KP505-CPP propeller under open water test conditions. The performance of the fixed pitch version at different advance coefficients is compared with the performance of the controllable pitch version. Different pitch angles were applied to the blades to adapt to changes in the advance coefficient.

The advance coefficient is given in equation 4, thrust coefficient is given in equation 5, torque coefficient is given in equation 6 and propeller efficiency is given in equation 7, which are frequently used to examine propeller performance under open water propeller test conditions.

$$J = \frac{V_a}{nD} \tag{4}$$

$$K_T = \frac{T}{\rho n^2 D^4} \tag{5}$$

$$K_Q = \frac{Q}{\rho n^2 D^5} \tag{6}$$

$$\eta_0 = \frac{K_T}{K_Q}\frac{J}{2\pi} \tag{7}$$

When the open water test results of the KCS/KP505 propeller used in the study are analyzed in Figure 6, it is seen that the highest efficiency point is realized at 0.8 advance coefficient at the design pitch of the propeller. It is seen that the efficiency decreases at lower advance coefficients before this point and at larger advance coefficients after this point. In this case, it is seen that as long as the pitch of the propeller remains constant, the propeller efficiency decreases significantly at low and high speeds and causes energy loss if the marine vessels using the propeller keep the shaft speed constant. Due to this situation, some geometrical modifications were made on the propeller, whose design conditions are FPP, and the propeller was transformed into a form that can be used as CPP. Thus, even if

the propeller speed is kept constant at low and high speeds, the efficiency obtained in the FPP version can be exceeded by changing the pitch.

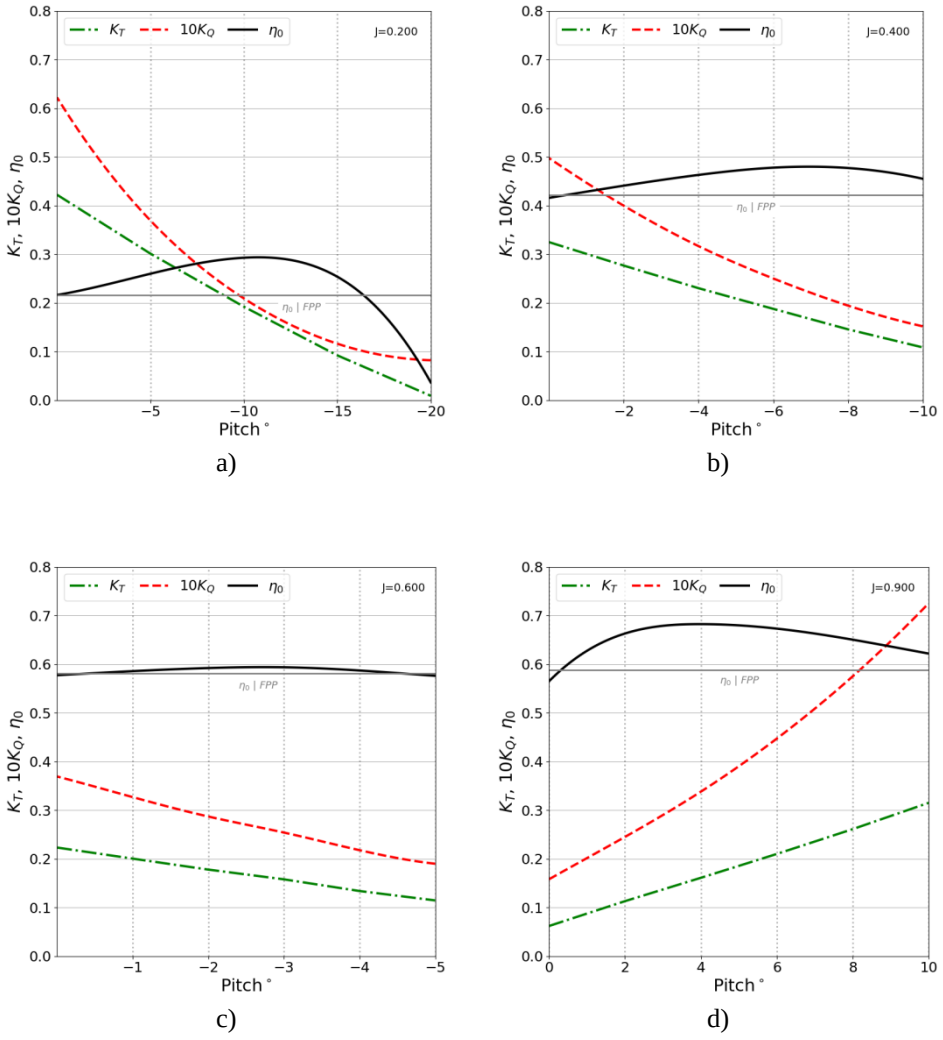

Figure 7. *Propeller performances for different pitch angles at a) J=0.2, b) J=0.4, c) J=0.6 and d) J=0.9 advance coefficients*

When the figure is examined, the efficiency value of the FPP version propeller is indicated as the threshold for the current advance coefficient in each graph. It is seen that the change in propeller pitch angle affects the propeller efficiency more as we move away from the optimum efficiency point under design conditions. In Figure 7.a, at the lowest vessel speed conditions, when the propeller pitch is moved in the negative direction by 12° compared to the design pitch, higher efficiency values are obtained according to the advance coefficient. In Figure 7.b, when the vessel speed increases a little more, it is understood that the optimum pitch angle should be moved in the negative direction of 7° compared to the design pitch. In Figure 7.c, it is seen that the optimum pitch angle is 2.5° in the negative direction for the case where the advance coefficient is very close to the advance coefficient where the highest efficiency is obtained. In Figure 7.d, it is seen that the optimum pitch changes direction and becomes 4° positive at the forward speed where the vessel speed exceeds the optimum efficiency point.

It is also understood from the figure that the increase in the propeller efficiency to be obtained by changing the pitch when approaching the advance coefficient where the highest efficiency is obtained under design conditions gives more limited values.

The pressure and wall shear stress distributions on the propeller blades at different pitch angles are given in Figure 8 for J=0.2, Figure 9 for J=0.4 and Figure 10 for J=0.9. Considering that the highest efficiency point in the design conditions is around J=0.8, it is understood that a negative pitch angle change is made in Figure 8 and Figure 9 and a positive pitch angle change is made in Figure 10. In Figure 8, it is noteworthy that in the application where the pitch angle is -10°, there is a near-uniform pressure distribution in front of the blade (Downstream face) and behind the blade (Upstream face) compared to the FPP propeller model. In the wall shear stress distributions, it is predicted that the wall shear stress decreases at the blade tips, especially at the blade rear face, and therefore the propeller torque requirement is also reduced.

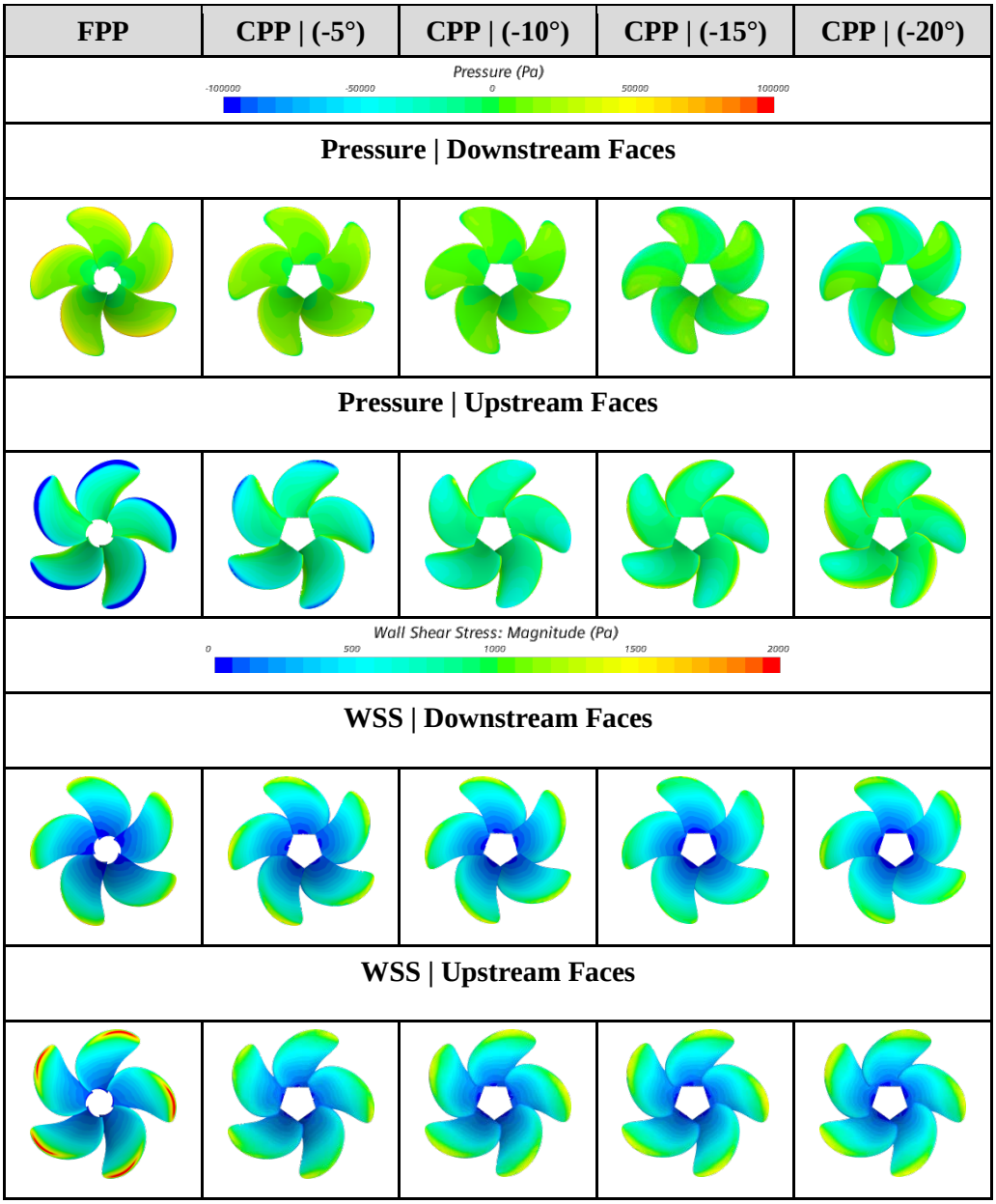

Figure 8. *Pressure and wall shear stress distributions on FPP version blades and CPP version blades at different pitch angles for J=0.2*

In Figure 9, it is seen that the optimal pitch angle change is around -6° and the surface distributions at this point are the same as in Figure 8 with homogeneity in pressure distribution and reduction in wall shear stress.

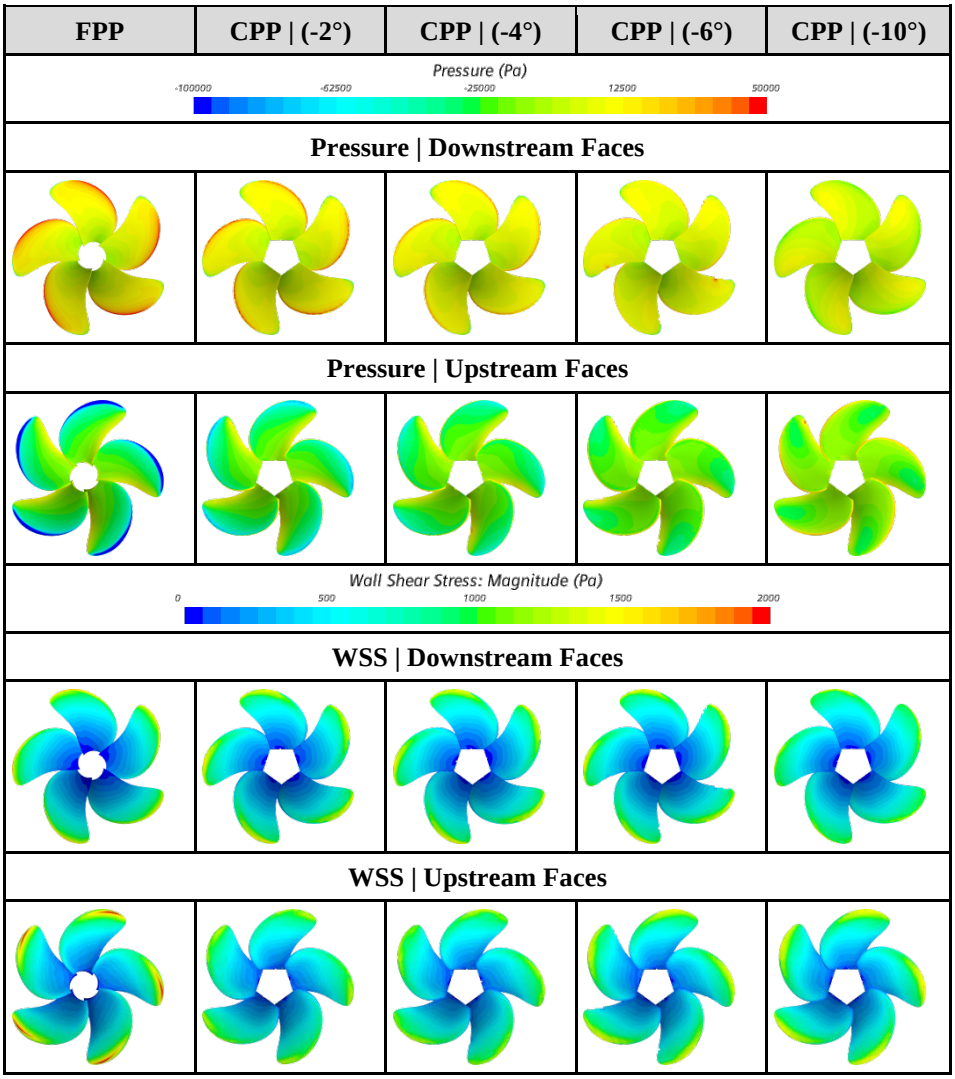

Figure 9. *Pressure and wall shear stress distributions on FPP version blades and CPP version blades at different pitch angles for J=0.4*

Figure 10 shows that in the model where the propeller pitch angle is in the positive direction and the optimal angle change is +4°, it is understood that there are increasing values in the end regions of the front face for the pressure distribution and decreasing values in the end regions of the back face for the wall shear stress distributions.

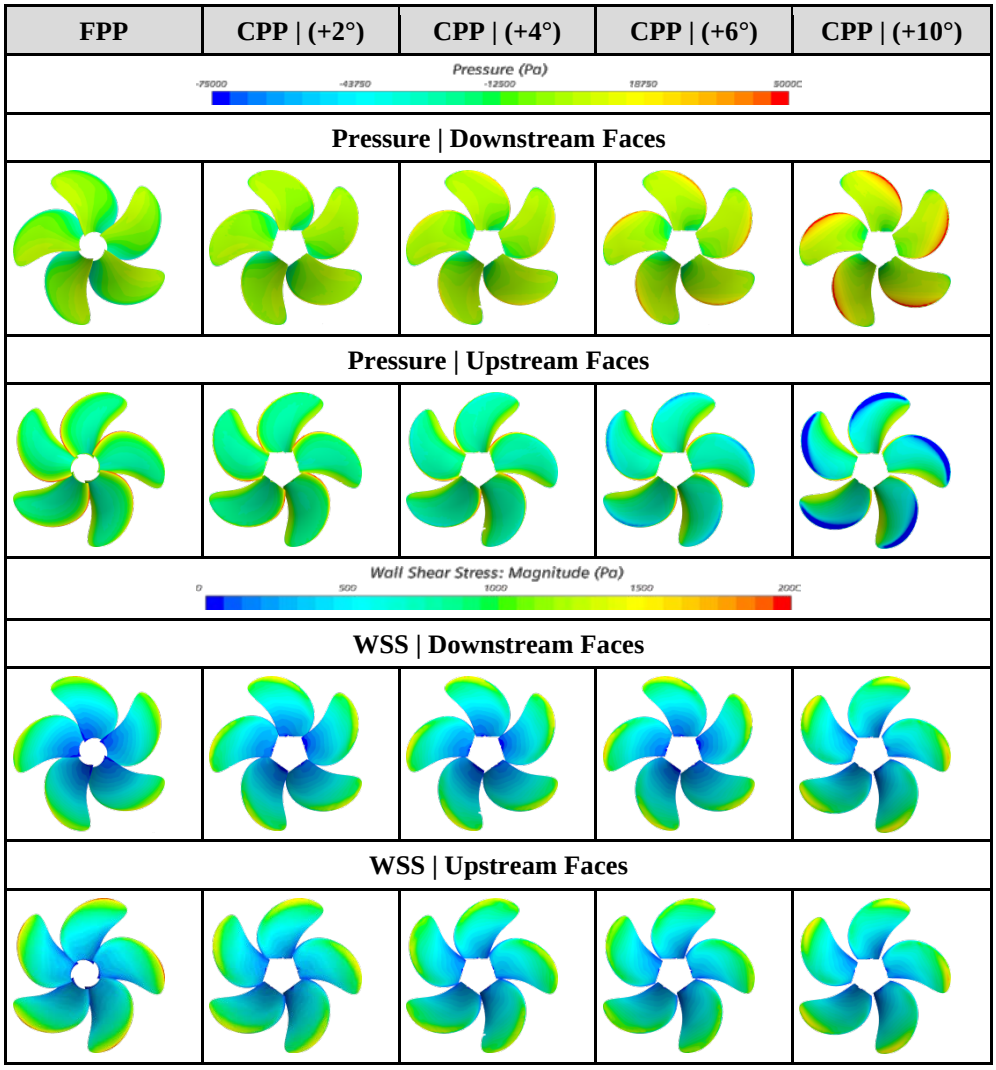

Figure 10. *Pressure and wall shear stress distributions on FPP version blades and CPP version blades at different pitch angles for J=0.9*

4. CONCLUSION

In this study, a test propeller designed as an FPP was made to operate with CPP principles by geometric modifications in the blade and hub geometry. The hydrodynamic performance of this modified propeller compared to its parent FPP propeller is investigated. It was observed that the efficiency of the FPP propeller decreased significantly, especially as the advance coefficient moved away from the optimum efficiency point in the design conditions. The modified CPP propeller has been developed with pitch changes and higher efficiency values have been obtained.

In modified CPP propellers, it is understood that the pitch of the propeller blades should be adjusted to a negative position at vessel speeds that give lower advance coefficients than the advance coefficient, which is the optimum efficiency point under design conditions, and to a positive position at vessel speeds that give higher advance coefficients.

It is understood that the farther away from the optimum efficiency point, the greater the contribution of the blade movements obtained with the modification to the efficiency.

In future studies, it is envisaged that researchers will make significant contributions to the literature by investigating both cavitation formation and hydro-acoustic investigations in such modified CPP propellers.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

DEVELOPMENT OF NOVEL COMPARISON BASED STEGANOGRAPHY ALGORITHMS ON MULTIMEDIA TO HIDE PRIVATE DATA

Musa MİLLİ[1*]
Daniyar KHASSENOV[2]

[1]*National Defence University, Turkish Naval Academy, Department of Computer Engineering, Istanbul, Turkiye, mmilli@dho.edu.tr*

[2]*National Defence University, Atatürk Strategic Research Institute, Istanbul, Turkiye, d.khassenov.88@gmail.com*

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ABSTRACT

Throughout history, humanity has had secrets to safeguard, information that needed to be conveyed to allies in a way that enemies couldn't decipher. To achieve this goal of safeguarding important and valuable information, cryptography and steganography have been frequently used methods both in the past and in today's world. This article introduces a steganographic algorithm designed for hiding data in the color images, along with two different algorithm designs derived from this method. The bits of the hidden message are embedded sequentially into each pixel using the bit comparison. The comparison method works by matching the bits of the image and the message. The least significant bits (LSB) of the carrier (cover) image bytes change depending on the number of matching bits between the carrier image and the hidden message. The proposed method has the potential to hide 1 byte of data within 5 bytes under optimal conditions. The designed algorithms have been tested on a series of color images, and satisfactory results have been achieved in terms of embedding a sufficient amount of data into the images without compromising image quality. The results have been compared with the results of the LSB technique and similar methods based on various performance criteria.

Keywords: *Comparison-based Steganography, Image Steganography, Least Significant Bit, Two-bit Steganography*

MULTİMEDYA ÜZERİNDE ÖZEL VERİLERİ GİZLEMEK İÇİN KARŞILAŞTIRMA TABANLI YENİ STEGANOGRAFİK ALGORİTMALARIN GELİŞTİRİLMESİ

ÖZ

Tarih boyunca insanlığın korunması gereken sırları ve düşmanların çözemeyeceği şekilde müttefiklere iletilmesi gereken bilgileri vardı. Bu önemli ve değerli bilgilerin korunması hedefine ulaşmak için kriptografi ve steganografi hem geçmişte hem de günümüz dünyasında sıklıkla kullanılan yöntemlerden olmuştur. Bu makale, renkli görüntüler üzerinde veri gizleyen stenografik bir algoritma tasarımı ve bu algoritmadan türeyen iki farklı algoritma tasarımını tanımlar. Gizli mesajın bitleri, karşılaştırma yöntemi kullanılarak her bir piksele sırayla gömülür. Karşılaştırma yöntemi, görüntünün ve mesajın bitlerini eşleştirerek çalışır. Taşıyıcı imge ile gizli mesajın eşleşen bitlerinin sayısına bağlı olarak, taşıyıcı imge baytlarının en önemsiz bitleri (LSB) değişir. Önerilen yöntem, optimal koşullar altında 5 bayt içerisinde 1 baytlık veriyi gizleme potansiyeline sahiptir. Tasarlanan algoritmalar bir dizi renkli görüntü üzerinde test edilmiş ve görüntü kalitesinden ödün vermeden yeterli miktarda verinin görüntülere gömülmesi açısından tatmin edici sonuçlar elde edilmiştir. Elde edilen sonuçlar farklı performans kriterlerine göre LSB tekniği ve benzer yöntemlerin sonuçları ile karşılaştırılmıştır.

Anahtar Kelimeler: *Karşılaştırma Tabanlı Steganografi, İmge Steganografisi, En Önemsiz Bit, İki-bit Steganografi*

1. INTRODUCTION

Steganography, derived from the Greek words "steganos" (meaning covered or concealed) and "graphia" (meaning writing or drawing), is the art and science of hiding one piece of information within another. Unlike encryption, which scrambles data to make it unreadable, steganography focuses on rendering data imperceptible to the human eye or automated algorithms. The initial stage on the path to knowledge and wisdom appears as raw data. The advancement of digital technologies has resulted in the creation of more data thanks to numerous IoT devices, scientific studies, social media, e-commerce, and video streams (Li et al., 2022; Milli & Milli, 2023). The generated data has become business intelligence, and as a result, a strategic advantage for those who process it into knowledge and

experience. For these reasons, in today's world, the storage, processing, and protection of data generated in the course of daily life have become increasingly important. Hence, in an age where information is both power and vulnerability, the need for secure communication and data protection has never been greater.

Throughout history, humanity has had secrets to safeguard, information that needed to be conveyed to allies in a way that enemies couldn't decipher. To achieve this goal of safeguarding important and valuable information, cryptography has been a frequently used method both in the past and in today's world. Encryption techniques allow you to secure a message in a manner that prevents outsiders from reading it. Nevertheless, when such a message is transmitted, an external observer will certainly be aware that an encrypted message has been sent, potentially attracting unwanted additional attention for both the sender and the receiver. If the transmitted message appears suspicious, an external observer (attacker) may attempt to decrypt the message, and in some cases, they may succeed. This means that confidential information could be compromised, resulting in its loss of value and significance. In the past, to avoid such situations and conceal the fact of transferring secret information, steganography has often been a frequently employed method. In contrast to cryptography, which aims to conceal the message's contents, steganography aims to hide the message's existence (Bansal & Badal, 2022). In other words, if cryptography makes the understandable unreadable, then steganography makes the visible invisible. The combination of steganography and cryptographic methods is often used, which complements each other.

Computer technologies and digital communication channels are currently advancing in the modern world, and information is frequently presented in the form of multimedia files. Therefore, in addition to older stenography methods, digital steganography has emerged, which uses digital media files to transmit confidential information. Media files are used as containers (carriers) where hidden information is embedded. As a container, it is possible to utilize various types of digital files, such as text documents, audio, images, videos, and so on. Detecting hidden information embedded within digital files is often not easily achievable through

human perception. Therefore, multimedia files containing hidden information can be securely transmitted through public communication channels. Indeed, the real strength of steganography lies in its ability to transmit hidden information through public channels. Because the transmission medium of the hidden multimedia file, the internet, contains a vast amount of similar types of files, the hidden file blends in with them.

The original multimedia file is referred to as the cover object. The embedding function is the technique used to conceal the desired data inside the cover object. To create a stego-object, sensitive data is concealed within the container object using a hiding method. Since the file format of the original object and the stego-object are the same, it is challenging for the human perceptual organs to distinguish any variations. After the stego-object containing the hidden message is transferred to the recipient, the recipient uses an extraction technique to acquire the desired hidden message. Figure 1 shows a general diagram of the steganographic data hiding and extraction data method.

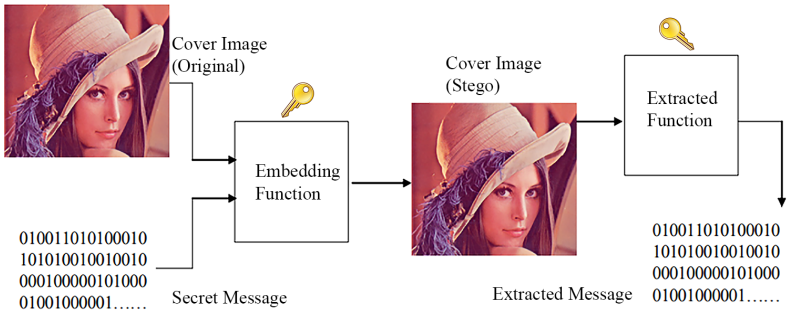

Figure 1. *General diagram of data hiding and data extraction with steganography.*

Some techniques require the original image to access the hidden message from the stego-object. Thus, from the perspective of message retrieval, it is possible to categorize steganography into two distinct classes: those that require a cover object and those that do not. In Figure 2, the classification schema of steganography, adapted from Yalman (Yalman, 2010) can be observed.

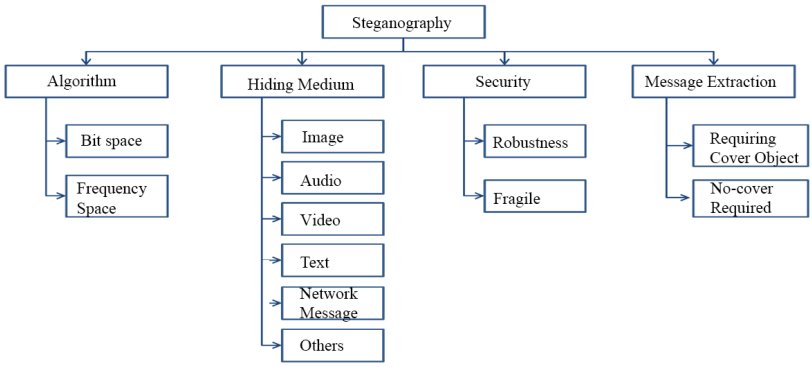

Figure 2. *Classification of stegonography adapted from (Yalman, 2010).*

Three main factors -capacity, robustness, and imperceptibility- determine the effectiveness of steganographic techniques. These factors are known as the "steganography triangle" (Khan & Sarfaraz, 2019). These properties of steganographic objects are often in a trade-off relationship with each other. For instance, when modifications are made to increase the capacity of a particular steganography method, it often negatively affects both robustness and imperceptibility. A steganographic approach is more compatible with classical steganography when its capacity is increased, while it is more compatible with secure steganography when its imperceptibility is increased, and it is more compatible with digital watermarking when its robustness is increased (Grībermans et al., 2016).

Capacity is one of the fundamental characteristics of steganography and refers to how much data a steganographic method can hide. In other words, it indicates the number of bits of secret message that can be concealed. Typically, higher capacity means the ability to hide more secret data. However, achieving a higher capacity may result in a compromise in imperceptibility or robustness, among other important factors. It's crucial to strike a balance between capacity and other features.

Robustness refers to how resistant the hidden message is to operations applied to the carrier medium (e.g., compression or resizing). It measures the ability of the

steganographic method to maintain the integrity of the hidden data even when the cover medium undergoes transformations. A robust steganographic method ensures that the hidden message remains intact despite potential alterations to the carrier. Balancing robustness with capacity and imperceptibility is essential for the overall effectiveness of steganography.

Imperceptibility refers to how well the stego-object (the cover object with hidden data) resembles the original, unaltered cover object. In steganography, it's crucial that any modifications made to the cover object are imperceptible to human perception. If the changes are too noticeable, the steganographic method becomes ineffective because it draws attention to the presence of hidden data. Achieving high imperceptibility while maintaining capacity and robustness is a challenging aspect of steganographic techniques.

The rest of the paper is organized as follows. A thorough analysis of the literature on bit-space and image steganography is provided in section 2. The theoretical designs of the developed methods are explained in section 3. In section 4 findings are presented and some performance criteria are discussed, and finally, the study is wrapped up with conclusions in section 5.

2. RELATED WORK

Image is the most common digital medium used for steganography. Digital images often contain a substantial amount of redundant data, making it easier to conceal a message within the image file, and they also offer ample capacity for this purpose. In digital systems, an image is made up of a numeric series that represents the various light intensities in different regions of the image. The smallest atomic unit of this numerical representation, which is an array, is known as a pixel and these pixels constitute the basis of the image. The steganography of images is made possible by leveraging the limited capabilities of the human visual system (HVS). When a specific digital color in the RGB color format is closely examined, it has been observed that changes in the least significant bits, which have lower significance, are imperceptible to the HVS. Indeed, it is evident that using the

potential of the human eye's perception, a pixel color with a value of (255, 255, 0) cannot be distinguished from a pixel color with a value of (254, 255, 0).

Sharp (Sharp, 2001) is one of the researchers who initially employed the substitution method. According to the approach he developed, unlike the LSB technique, when the last bit of the following byte in the carrier image matches the bit to be hidden, that bit remains unchanged. When the last bit of the next byte in the carrier file is different from the bit to be hidden, the byte value of the container file is either incremented by 1 or decremented by 1. Milikainen (Mielikainen, 2006) is another pioneer who hides data by using the substitution method in his studies. The proposed method operates by hiding 2-bit data in two consecutive pixels in the cover object. Chan (Chan, 2009) improved upon Melikainen's method and proposed a new approach. By hiding one bit per pixel, Chan's proposed technique uses the XOR operator as a function and seeks to affect the image as little as possible. In his proposed method, Tian (Tian, 2003) created a strategy that minimizes image distortion, provides high capacity, and is difficult to reverse. In the proposed method, data is concealed in the area created by doubling the difference between two consecutive pixels in the cover image. Alattar (Alattar, 2004) improved upon Tian's proposed method by enhancing the difference between four consecutive pixels by a factor of two, allowing for the concealment of 3-bit data in the resulting area. Chang et al. (Chang et al., 2009) created two distinct stego-images in their developed approach. In the developed method, data is concealed in two images created using a modulation matrix and a change direction. The method exhibits a substantial data concealment capacity due to its utilization of two images. Lu et al. (Lu et al., 2015) proposed an alternative method by enhancing the approach suggested by Chang (Chang et al., 2009). The method provides high data hiding capacity alongside high image quality in pixel container images. In the study conducted by Ker (Ker, 2004), three pixels are used to conceal two data bits. While the last bits of two pixels are used for data hiding, the third one indicates whether the embedded image contains hidden data or not. Wu and Tsai (Wu & Tsai, 2003) proposed a method of concealing data using the pixel differencing technique. In this method, differences in pixel values are calculated in

a way that consecutive pixels in the container image do not overlap. The possible values of differences are represented by different classes. Building on the research of Wu and Tsai (Wu & Tsai, 2003), Wang et al. (C.-M. Wang et al., 2008) offered a novel approach. The method operates based on concealing data using the result of the modulus function of the difference between two pixels. Experimental results have revealed that the algorithm developed by Wang et al. outperforms previously suggested algorithms in the literature (Saran & Olcay, 2013).

In addition to the traditional methods described above, there are also state-of-the-art studies available. Two distinct steganographic approaches are described in Swain(Swain, 2018). One of these approaches works by dividing the image into 2x3 pixel blocks, while the other one operates with 3x3 pixel blocks. Only one pixel's value is altered within each block, and the difference values of neighboring pixels are calculated with respect to the changed pixel's new value. The method is more challenging to detect using steganalysis techniques compared to traditional methods because it makes decisions based on the pixel values of the cover image, like our proposed method.

In the study conducted in 2021, Durdu (Durdu, 2021) carried out research on image hiding within images, distinct from the studies mentioned above. In the proposed study, 24-bit color images are divided into 4-bit chunks, and each 4-bit chunk is reduced to 2 bits. In the process of retrieving the hidden image, the 2-bit data is reversibly transformed into 4 bits, and the 24-bit image is reconstructed by combining them in this manner. Given that 2-bit representations of 4-bit image blocks exist, some data loss is inevitable. However, due to the reduction in the size of the data to be concealed, twice as much data can be hidden compared to the traditional LSB method.

The structure of the cover object has a significant impact on how well data can be hidden within a digital item. Due to this, several researchers (Volkhonskiy et al., 2020; Zi et al., 2018) have created images using artificial intelligence methods that are better suited for data concealment as opposed to using already-existing images. In their 2020 study, Volkhonskiy et al. (Volkhonskiy et al., 2020) generated cover

images using the Generative Adversarial Networks (GANs) technique and concealed data into the generated image using the LSB embedding algorithm.

3. THE PROPOSED SUBSTITUTION BASED METHODS

Three different data-hiding techniques based on the comparison approach have been developed in the paper, and bitmap (BMP) images were used for the experimental evaluation of these techniques. The three developed methods have been named sequentially as comparison method 1 (CM-1), comparison method 2 (CM-2), and comparison method 3 (CM-3).

3.1. 2-bit comparison-based steganography method (CM-1)

RGB-based image files consist of pixels, with each pixel having three different values, each comprised of 8 bits. So, a pixel contains 24 bits of color data, organized as 8 bits for Red, 8 bits for Green, and 8 bits for Blue, in that order. In the classic LSB method, a single bit of data is embedded into the least significant bit (LSB) of each 8-bit color value, representing a pixel. Thus, each pixel conceals 3 bits of data.

The subject byte of the cover image is divided into two fields called the matching field and the position field. The matching field has six bits consisting of three-bit pairs, and the position field has two bits. The developed 2-bit comparison method (CM-1) sequentially compares 2 bits of hidden information with the bit pairs of the matching field and the match information is stored position field if the bit pairs to be hidden match any two bits in the cover image. As a result, the created solution only slightly modifies the cover image.

As seen in Table 1, the CM-1 method divides each hidden information byte into four to create matched bits. Additionally, by taking the first pair of a byte of hidden information, it compares it in pairs with the image bits. If the first two bits of the cover image byte match the two bits to be hidden, the last two bits of the cover image are set to 00; if it matches with the second pair, they are set to 01, and if it matches with the third pair, they are set to 10. If there is no match, then the last two bits are set to 11, and the value of the unmatched pair of hidden information bits

replaces the 5th and 6th bits. b_i and b_{i+1} are the first and second bits of hidden data, respectively. This way, to be used in the process of extracting hidden data, the position of the stored information in the stego-image is indicated in the last two bits. The working principle of the CM-1 method is illustrated in Figure 3.

Table 1. *The identity table and position values of the CM-1 method.*

The comparison table between the bit pairs of the hidden message and the bit pairs of the cover image.	The configuration of the final two bit pairs in every byte of the stego-image. (position field)
first pair (1st and 2nd Bit)	0 0
second pair (3rd and 4th Bit)	0 1
third pair (5th and 6th Bit)	1 0
no match	b_i b_{i+1} 1 1 (The unmatched bits of the hidden message are written in place of the 5th and 6th bits of the cover image.)

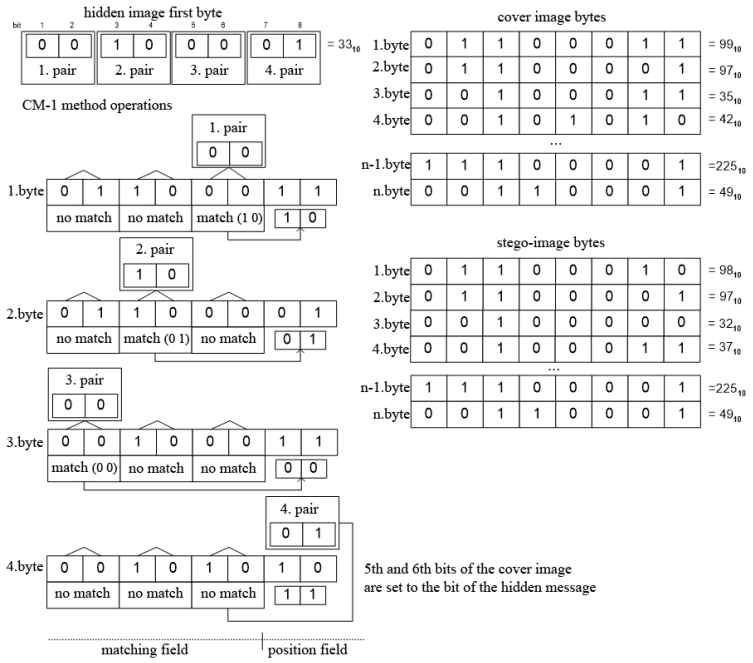

Figure 3. *Operating concept of the CM-1 method.*

Although the location for concealing data may work stochastically with respect to the structure of the cover image, the capacity is determined deterministically and remains constant for any cover image. In other words, the CM-1 method can embed 1 byte of data into 4 bytes of cover-image. However, the rate of change in the cover image varies stochastically depending on the cover image structure itself. The cover image will not change in the best-case scenario if the concealed message's bits match the matching field bits and the last two bits remain unchanged. Otherwise, the 5th and 6th bits of the image byte change resulting in maximum alterations in the stego-image. With the CM-1 method, an alteration ranging from 0% to 6.25% can occur in the image.

3.2. 4-bit comparison-based steganography method (CM-2)

In the CM-2 method, similar to the CM-1 method, the procedure of comparing similar bits and specifying their positions is followed. However, in this method, the bytes of the hidden message are not divided into pairs of 2 bits. Instead, in the CM-2 method, the hidden data is divided into 4-bit chunks, and comparisons are made with 4-bit segments of the cover image. Unlike the CM-1 method, even though 4-bit comparisons are made, it is not expected that all 4 bits will match. The matching process stops at the bit where the match ends, and it does not continue. That is, starting with the first bit of the secret message, it is compared to the cover image bits sequentially. If the bits match, one bit is added at a time and 4 bits in the chunk are tried to be completed. In the worst case, when the bits of the secret message do not match the bits of the cover image, the still valid byte of the cover image is used to conceal the bits of the message. Table 2 illustrates the bit conditions of the cover image, both in situations where matching takes place and when it does not. Here, the b_i value represents the next bit to be concealed.

When the proposed CM-2 algorithm is compared to the CM-1 algorithm, it can be observed that the maximum data-hiding potential of the CM-2 algorithm is lower. Although the CM-2 algorithm offers a lower capacity, at 30%, its detectability has significantly decreased compared to the CM-1 algorithm and traditional algorithms.

In other words, the CM-2 method results in such a minimal visual difference between the stego-image and the original image that it is nearly imperceptible.

Table 2. *The identity table and position values of the CM-2 method.*

The comparison table between the bit pairs of the hidden message and the bit pairs of the cover image.	The configuration of the last three bits in every byte of the stego-image. (position field)
1st bit	0 0 1
2nd bit	0 1 1
3rd bit	1 0 1
4th bit	1 1 1
no match	b_i 0

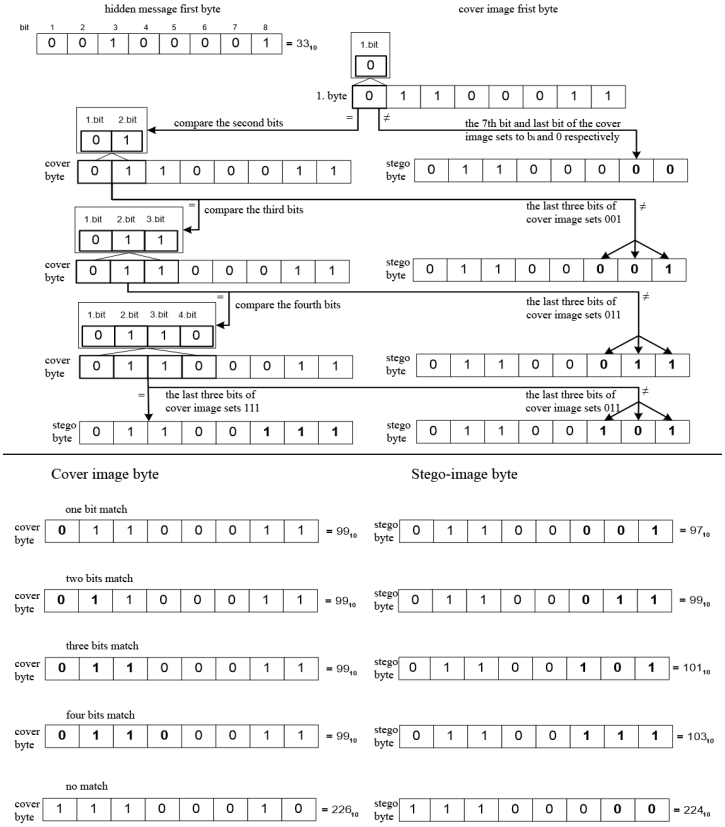

Figure 4. *Operating concept of the CM-2 method.*

In Figure 4, the working principle of the CM-2 method is illustrated. In the process of hiding data, the first step is to check for a match between the leftmost bit of the hidden message and the first bit of the cover image. If the first bits are not equal, the 7^{th} bit of the cover image byte is set to the hidden message bit, and the last bit is set to 0 (zero). In cases of one-bit, two-bit, three-bit, and four-bit matches, the last three bits of the cover image are set to 001, 011, 101, and 111, respectively.

The proposed CM-2 method can potentially cause a maximum of 3-bit changes for 4-bit hidden data. Besides, the CM-2 method has the potential to hide 1 byte of data within 2 bytes of data. Although the traditional LSB method changes 1 bit for 1 bit of data, it can embed 1 byte of data into 8 bytes of the cover image. Taking into account the bit values, while the CM-2 method results in 7 times more changes compared to the LSB method, it can embed 4 times more data than the LSB method in the ideal scenario.

3.3. 3-bit comparison-based steganography method (CM-3)

The CM-3 method follows a similar approach to the procedures described above, which involve comparing similar bits and specifying their positions. The cover image, however, is separated into 2-byte chunks in this technique. The first three bits of the secret message byte are matched with the first three bits of the first byte of the cover image, respectively, and it is checked whether they are equal. Information about the number of matched bits or non-matching situations is written to the 8^{th} bit of the 2-byte chunk in question. Table 3 illustrates how the cover image bytes change in matching and non-matching situations, and Figure 5 provides a schematic representation of the CM-3 method's operation.

In comparison to the previously described CM-1 and CM-2 algorithms, the CM-3 technique conceals a lower quantity of data. Experimental studies have shown that the capacity provided by the CM-3 algorithm is 64% lower than that provided by the CM-1 algorithm. In contrast, the criteria of imperceptibility, one of the quality criteria for steganographic objects, has increased. Furthermore, the CM-3 method is competitive in terms of all three quality criteria (capacity, robustness, and imperceptibility) when compared to previous studies.

Table 3. *The identity table and position values of the CM-3 method.*

Comparison between the bits of the hidden message and the first byte bits of the carrier image in each chunk.	The configuration of the last bits in every byte of the stego-image chunks. (position field)
1st bit	last bit of 1. byte = 0 last bit of 2. byte = 0
2nd bit	last bit of 1. byte = 0 last bit of 2. byte =1
3rd bit	last bit of 1. byte = 1 last bit of 2. byte = 0
no match	last bit of 1. byte = 0 last two bits of 2. byte = b_i 1

Figure 5 explains the flowchart of the CM-3 method. In the data hiding process, the first step involves checking the equality of the first bits of the hidden message and the cover image's first bytes. In case of no match, the last bits of the cover image's first and second byte are set to 1, and the 7th bit of the second byte is set to the non-matching bit of the secret message. When the first bits match, the matching of the second and third bits is checked in order, and the last bits of each of the two bytes in the cover image are set to 00, 01, and 10 respectively.

The CM-3 method accomplishes 2-bit modifications in the cover image for hidden messages ranging from 1 to 3 bits. In other words, under ideal conditions, the suggested CM-3 method allows for the hiding of 1 byte of data inside 6 bytes of cover image. While theoretically, the CM-3 method can store up to 32.76 KBytes of text within a 256x256 pixel image, experiments have shown that on average, around 16 KBytes of data can be stored in a random image. The traditional LSB method allows for the storage of up to 24.57 KBytes of data within the same size image. Considering the performance criteria of steganographic methods, it becomes evident that the developed CM-3 method holds the potential to compete with traditional LSB methods and other counterparts.

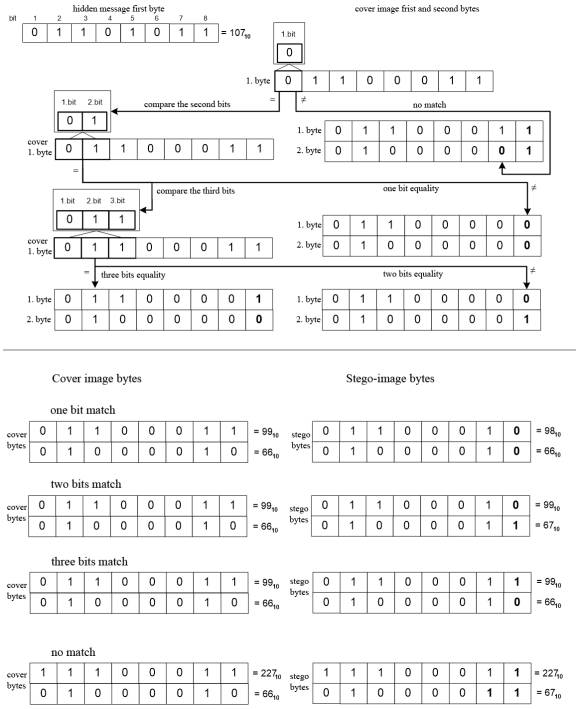

Figure 5. *Operating concept of the CM-3 method.*

4. EXPERIMENTAL RESULTS AND DISCUSSION

This section discusses the performance of the proposed approaches using experimental findings. The proposed methods were tested on a variety of images with different characteristics (standard, complex, plain-colored, etc.) commonly used in the field of steganography. Several outcomes have been provided in order to illustrate the efficacy and performance of the developed methods as measured by commonly used metrics: Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE).

The maximum number of bits that may be embedded in a fixed-sized image is commonly characterized as image capacity. Proposed methods, hide the data considering the bits of the cover image, which makes it challenging to determine

capacity in a general sense, as it depends on the bit structure of the cover image. However, theoretically, one can discuss the maximum and minimum capacity for the proposed methods. Given that capacity is one of the key performance criteria in steganography algorithms, it has been considered when discussing the findings.

In many studies in the literature, criteria that involve comparing the stego-image with the original image are frequently used to detect any distortions in steganographic images after the data-hiding process. MSE (Equation 1), PSNR (Equation 2), and Structural Similarity Index Measure (SSIM) (Equation 3) (Z. Wang et al., 2004) are commonly used evaluation measures to assess the quality and extent of changes in steganographic images. SSIM is a numerical method for calculating the similarity of two images. The SSIM index is a full-reference metric, meaning that the measurement or estimation of image quality relies on a reference, typically an uncompressed or undistorted original image. In Equation 1, *m* and *n* represent the row and column information of the image; *O* represents the original image, and *S* represents the stego-image. The PSNR is calculated once the MSE value has been obtained. *MAX* denotes the maximum value a pixel may have in Equation 2, which is 255 for RGB. In Equation 3, SSIM is calculated for different image windows. Where μ_x and μ_y are the pixel values mean of *x* and *y* images respectively. The μ_x^2 and μ_y^2 are the variance values of *x* and *y* images respectively. The σ_{xy} is the covariance of *x* and *y*. c_1 and c_2 are the variables to stabilize the division with weak denominator.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[O(i,j) - S(i,j)] \quad (1)$$

$$PSNR = 10log_{10}(\frac{MAX^2}{MSE}) \quad (2)$$

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (3)$$

The Lena (640x480), Bird (500x400), Baboon (400x300), and Peppers (640x480) images, which have been commonly used in previous research studies, were also selected for experimental purposes in this study. The stego-images obtained by hiding 500 bytes of data using the developed methods and the original images are

depicted in Figure 6. Examining the created stego-images and the original images, no changes can be perceived by human sensory organs.

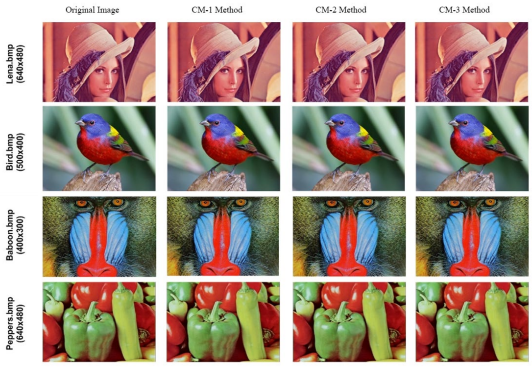

Figure 6. *Stego-images with 500 bytes embedded and the original images.*

In Table 4, a comparison of the results of the proposed methods and the work of Wu and Tsai has been conducted using the MSE and PSNR metrics. Developed CM-1, CM-2, and CM-3 methods, which can embed a substantial amount of hidden data, have yielded MSE and PSNR values comparable to their counterparts. The PSNR values obtained for the proposed methods demonstrate that the degradation in the stego-image is minimal. The CM-3 method, in particular, is more effective in terms of PSNR values despite having a lesser data embedding capacity than the CM-1 and CM-2 methods.

A high PSNR value obtained after data hiding implies a high degree of similarity between the cover image and the original image. In other words, a higher PSNR value indicates that the steganography method has made fewer changes to the cover image. Small MSE values, on the other hand, suggest that the method is better. All three developed methods embed data depending on the structure of the cover image, as seen in Table 4, substantial PSNR variations are observed for different images. Upon evaluating the findings, it is evident that the CM-3 method demonstrates superiority over the other methods (CM-1, CM-2, and Wu & Tsai). Furthermore, MSE values have been calculated for the stego-images generated after the hiding process for each compared method. The results obtained by hiding

messages of different sizes in four different images used in experimental studies are shown in Table 4, and the average of these results is presented in the following figures. The figures depicting the average MSE and PSNR values calculated for each method are provided in Figure 7 and Figure 8, respectively. Considering the averages, the results also establish that the CM-3 method offers the best outcome.

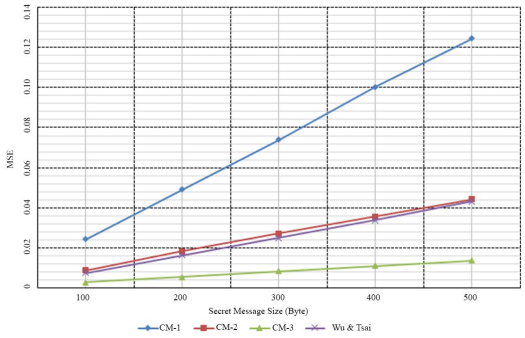

Figure 7. *The average MSE values of stego-images produced by hiding secret data of varying sizes.*

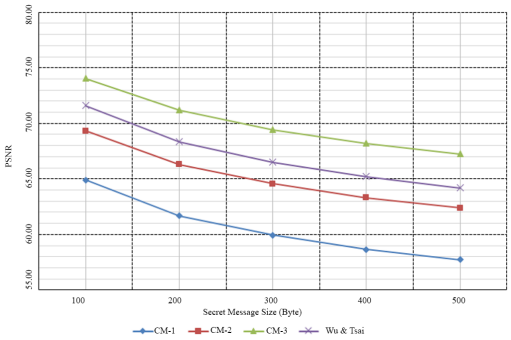

Figure 8. *The average PSNR values of stego-images produced by hiding secret data of varying sizes.*

In the parametric analysis, one of the measured values is the changing number of bits. Table 5 presents the number of bits changing obtained from the parametric analysis. Based on this experimental investigation, it is evident that the stego-image obtained using the CM-1 approach has the least amount of bit modification.

When the bit alteration parameter was considered, the proposed techniques CM-2 and CM-3 produced inferior results than the CM-1 method. However, they have produced better results compared to the method proposed by Wu & Tsai.

Table 4. *Comparison of proposed and equivalent methods with each other.*

	Lena.bmp		Bird.bmp		Baboon.bmp		Peppers.bmp		Method
	MSE	PSNR(db)	MSE	PSNR(db)	MSE	PSNR(db)	MSE	PSNR(db)	
100	0.0106	67.8445	0.0192	65.2823	0.0263	63.9266	0.0108	67.7897	**CM-1**
	0.0035	72.5937	0.0060	70.2929	0.0104	67.9327	0.0038	72.2446	**CM-2**
	0.0014	**76.5344**	**0.0017**	**75.6266**	**0.0033**	**72.8875**	0.0019	75.1970	**CM-3**
	0.0014	76.4026	0.0026	73.9120	0.0109	67.7543	**0.0018**	**75.3682**	**Wu & Tsai**
200	0.0216	64.7689	0.0344	62.7618	0.0525	60.9285	0.0336	62.8570	**CM-1**
	0.0071	69.6038	0.0129	67.0069	0.0207	64.9687	0.0071	69.6171	**CM-2**
	0.0029	**73.4305**	**0.0035**	**72.6818**	**0.0066**	**69.8989**	**0.0031**	**73.1567**	**CM-3**
	0.0033	72.9190	0.0053	70.8149	0.0282	63.6278	0.0037	72.3554	**Wu & Tsai**
300	0.0312	63.1768	0.0504	61.0986	0.0823	58.9741	0.0506	61.0809	**CM-1**
	0.0108	67.7818	0.0187	65.3923	0.0318	63.0974	0.0106	67.8489	**CM-2**
	0.0042	**71.8655**	**0.0053**	**70.8744**	**0.0099**	**68.1513**	**0.0049**	**71.2238**	**CM-3**
	0.0048	71.2431	0.0082	68.9873	0.0454	61.5570	0.0058	70.4764	**Wu & Tsai**
400	0.0415	61.9416	0.0726	59.5195	0.1100	57.7164	0.0632	60.1225	**CM-1**
	0.0146	66.4799	0.0250	64.1467	0.0417	61.9199	0.0153	66.2738	**CM-2**
	0.0055	**70.6928**	**0.0071**	**69.6039**	**0.0133**	**66.8787**	**0.0065**	**69.9386**	**CM-3**
	0.0066	69.9030	0.0110	67.6919	0.0636	60.0909	0.0073	69.4390	**Wu & Tsai**
500	0.0515	61.0122	0.0901	58.5803	0.1349	56.8287	0.0720	59.5553	**CM-1**
	0.0181	65.5410	0.0307	63.2525	0.0521	60.9566	0.0185	65.4559	**CM-2**
	0.0068	**69.7539**	**0.0088**	**68.6434**	**0.0167**	**65.8813**	**0.0079**	**69.1186**	**CM-3**
	0.0083	68.9339	0.0140	66.6581	0.0822	58.9776	0.0092	68.4550	**Wu & Tsai**

Table 5. *The changing numbers of bits obtained through the parametric analysis of the compared methods.*

	Lena	Bird	Baboon	Peppers
	640 * 480	500 * 400	400 * 300	640 * 480
CM-1	**3037**	**3096**	**3092**	**3333**
CM-2	3592	3585	3652	3700
CM-3	3772	3508	3654	3965
Wu & Tsai	3999	4321	3777	4101

One of the essential assessment criteria for a steganographic method is the amount of data it can hide. As a result, the proposed algorithms and traditional methods have been assessed based on their data-hiding potential using the images employed in experimental studies. The findings are presented in Table 6, and based on the results, the CM-1 method demonstrates the highest capacity. The developed CM-1 method has the potential to embed two times as much data compared to the classic LSB method and three times as much data compared to Wu & Tsai's method. There is no doubt that the discussed criteria are theoretical potentials, but appropriate images for the method can be found or generated using artificial intelligence tools.

Table 6. *Comparison of the maximum bit embedding capacities of the developed methods and traditional methods.*

	Lena	**Bird**	**Baboon**	**Peppers**
Size	640 * 480	500 * 400	400 * 300	640 * 480
LSB	116 350 byte	75 750 byte	45 450 byte	116 318 byte
CM-1	**232 704 byte**	**151 500 byte**	**90 902 byte**	**232 718 byte**
CM-2	163 840 byte	106 166 byte	62 208 byte	158 671 byte
CM-3	77 467 byte	51 106 byte	30 261 byte	76 962 byte
Wu & Tsai	67 129 byte	44 638 byte	29 951 byte	66 598 byte

In addition to the advantages of the developed algorithms such as high capacity and imperceptibility, their detection by steganalysis methods is equally challenging. Traditional LSB and LSB-based methods embed one or two bits per byte in the cover image using a deterministic approach, whereas the three developed methods embed hidden messages in locations that vary according to the structure and bit sequence of the cover image. Thus, it is impossible to predict where the developed method will embed any bit of the hidden message without knowledge of the algorithm. Indeed, the regions in which the CM-2 and CM-3 methods made changes on a bird image can be clearly seen in Figure 9. The images at the top in Figure 9 belong to the CM-2 method. The first one represents the original image, the second one the stego-image, and the subsequent images illustrate where the bit corruptions are prevalent. Similarly, in Figure 9, the images at the bottom belong to the CM-3 method. Examining areas with intense bit corruption, it becomes evident

that predicting where the corruption will occur is not feasible. From this perspective, the developed methods outperform traditional LSB-based techniques.

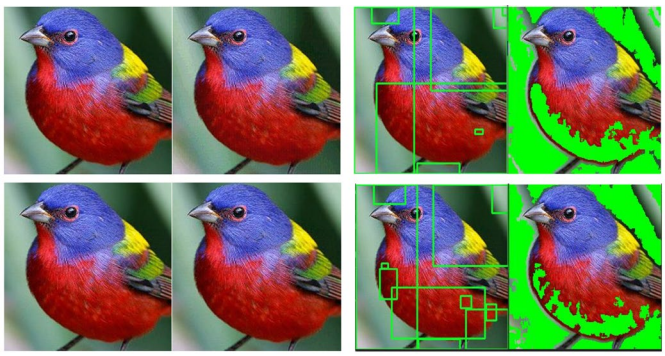

Figure 9. *Original images, stego-images, and regions with corruptions (the images above belong to CM-2, the images below belong to CM-3).*

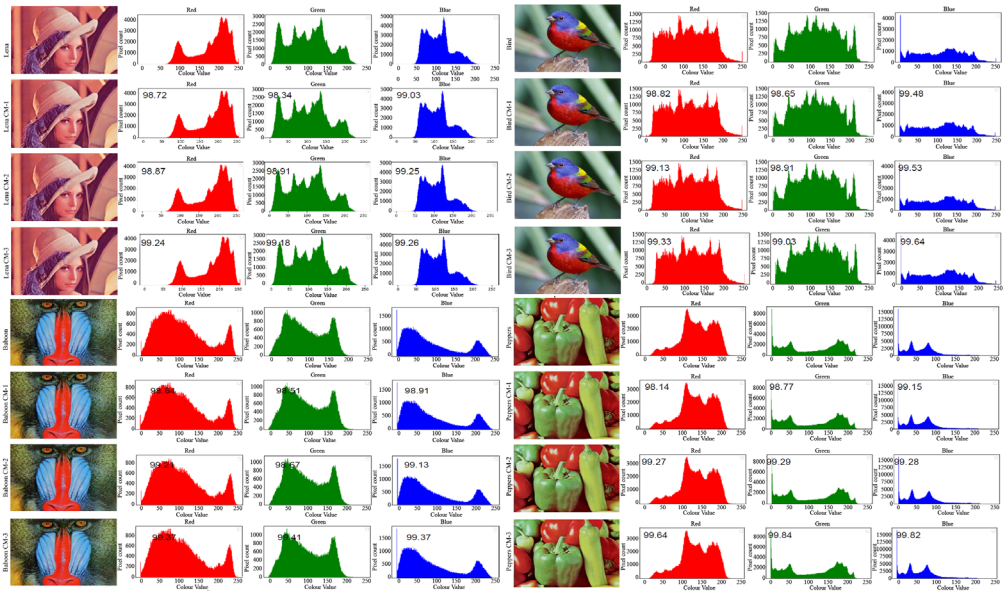

Figure 10. *Comparison of histograms between the original and stego-images.*

The frequency graph of pixel intensities in an image is referred to as a histogram. A histogram provides information about how many pixels have each color value in an

image. During data embedding, the pixel value changes, causing a change in the color value as well. It's a measure used in steganography and indicates how much the color values of the stego-image have changed. It is expected that the color values remain unchanged or that any changes are minimal. Figure 10 displays the results of an experimental study that illustrates how much the color histograms have changed after the process of embedding 500 bytes of data into different images using the three developed methods. In this experiment, the CM-3 method has achieved results that are closer to the original image's color values for each image. This indicates that the CM-3 method made fewer changes in the image when considering the color histogram.

5. CONCLUSION

There are many different steganography methods that work with images in various formats, both color and grayscale. Many approaches frequently employ sophisticated mathematics to produce effective outcomes. Some of these methods use the original image to extract hidden data. The study has proposed new and effective methods for hiding data in images without causing noticeable alterations. In the proposed method CM-1, data up to 3 bits can cause changes within 2 bytes. In other words, the CM-1 has the potential to hide 1 byte of data within 5 bytes under optimal conditions. The proposed methods use similarity and comparison tactics without complex mathematical calculations. This makes them time-efficient, as they don't involve high-time complexities. Moreover, the proposed methods are relatively simple and straightforward to apply to RGB color images compared to some of their counterparts. Even if the stego-image is obtained by third parties, it is not possible to extract the hidden data without knowledge of the algorithm. To extract embedded data from a stego-image, there is no need to refer to the original image.

Based on the results obtained from the experimental studies, it is evident that the developed CM-3 method achieved more effective results in terms of the PSNR and MSE metrics. There is a difference of at least 4.5 units between the results of the CM-3 method and the Wu and Tsai algorithm. However, in terms of data

embedding capacity, the leading method in this field with the best results is CM-1. In steganography, there is a trade-off between capacity and its imperceptibility. When this trade-off is examined in the context of the developed methods, it is evident that CM-1 has a high data-hiding capacity while having relatively lower imperceptibility. Conversely, CM-3 exhibits the opposite characteristics, with a low data-hiding capacity and high imperceptibility.

The experimental findings reveal that the suggested approaches preserve the acceptable visual quality of stego-images while adequately fulfilling the requirements of steganography.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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RESEARCH ARTICLE

**An ethical committee approval and/or legal/special permission has not been required within the scope of this study.*

DESIGN AND OPTIMIZATION OF A DUAL-BAND IRIS POLARIZER

Merve GÜVENÇ[1,2]*
İsmail ŞİŞMAN[1]
A. Arif ERGİN[2]

[1]Profen Communications Technologies, Istanbul, Turkey, merve.guvenc@profen.com, ismail.sisman@profen.com

[2]Yeditepe University, Department of Electrical & Electronics Engineering, Istanbul, Turkey, merve.guvenc@std.yeditepe.edu.tr, arif.ergin@yeditepe.edu.tr

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ABSTRACT

The structure that transforms a linear polarized signal into right-hand or left-hand circularly polarized signals is called a polarizer. In this study, a dual-band waveguide polarizer used in satellite communications is presented. The waveguide polarizer is designed using iris structures on a square waveguide. The purpose of the polarizer is to transmit the ±45° tilted linearly polarized signal at its input to the output as a right-hand or left-hand circularly polarized wave, and vice versa. At the input of the polarizer, a transition is designed between the WR42 waveguide and the square waveguide. At the output stage, a transition from square waveguide to circular waveguide is designed. In this paper, the design steps of both the polarizer and the transition sections, the optimization parameters, and simulation results are presented in full detail. The simulations are performed with a commercial electromagnetic simulation software, CST Studio Suite. The design operates within the Ka-band, specifically at 17.2 – 21.2 GHz and 27.5 – 31 GHz frequency bands. The insertion loss of the iris polarizer is <0.05 dB, the return loss is >23 dB, and the phase difference is less than 15° around 90° for both bands.

Keywords: Iris Polarizer, Dual-Band Polarizer, Ka-Band.

ÇİFT-BANT İRİS POLARİZÖR TASARIM VE OPTİMİZASYONU

ÖZ

Doğrusal polarizasyonlu bir sinyali sağ-el veya sol-el dairesel polarizasyonlu bir sinyale dönüştüren yapılar polarizör olarak adlandırılmaktadır. Bu çalışmada, uydu haberleşmesinde kullanılan çift-bant dalga kılavuzu polarizör tanıtılmıştır. Dalga kılavuzu polarizör, kare dalga kılavuzu üzerine iris yapıları kullanılarak tasarlanmıştır. Polarizörün amacı, girişine gelen ±45° yatık doğrusal polarizasyonlu sinyali çıkışına sağ-el ya da sol-el dairesel polarizasyona sahip dalga olarak iletmektir. Polarizörün girişinde WR42 dalga kılavuzu ile kare dalga kılavuzu arasında bir geçiş kısmı tasarlanmıştır. Çıkışında ise kare dalga kılavuzundan dairesel dalga kılavuzuna geçiş tasarlanmıştır. Bu dokümanda, polarizörün ve geçiş kısımlarının tasarım adımları, optimizasyon sonucunda elde edilen parametreler ve simülasyon sonuçları tüm ayrıntıları ile sunulmuştur. Simülasyonlar, ticari bir elektromanyetik simülasyon programı olan CST Studio Suite ile gerçekleştirilmiştir. Tasarım Ka bantta, 17.2 – 21.2 GHz ve 27.5 – 31 GHz frekans aralıklarında çalışmaktadır. İris polarizörün araya girme kaybı <0.05 dB, geri dönüş kaybı >23 dB ve faz farkı iki bant için de 90° etrafında 15°'den küçüktür.

Anahtar Kelimeler: *İris Polarizör, Çift Bant Polarizör, Ka Bant.*

1. INTRODUCTION

Antennas are structures that enable the propagation and receiving of electromagnetic waves. Antenna design depends on the polarization type of the wave and the field of application.

Antennas are inevitably used in satellite communications, where signal transmission by cable is impossible. Satellite communications is one of the most studied areas in space operations (Kolawole, 2002). The main purpose of a communication satellite is to assist in the transmission of information or messages from one point to another in space. The transmitted information can be audio, video, or digital data. This information can also be transmitted from the earth to the satellite or vice versa. The transmitted wave between the earth and the satellite passes through the ionosphere. As the wave passes through the ionosphere, the wave may rotate due to free electrons in the ionosphere, and the polarization direction of the wave may change. Since

circularly polarized waves are not affected by polarization rotations in the ionosphere, they are preferred in satellite communications (Dondl, 1995). The device that is called a polarizer is used to convert a linearly polarized wave into a circularly polarized wave (or vice versa) (Kitsuregawa, 1990). There are different types of polarizers depending on the frequency and area of application. Septum polarizer, circular polarizer, corrugated polarizer, and iris polarizer are some of the most commonly used polarizers (Eom & Korchemkin, 2006) (Jazani & Pirhadi, 2018) (Tribak, Mediavilla, Cano, Boussouis, & Cepero, 2009) (Güvenç, Şişman, & Ergin, 2023). The structure of the iris polarizer is especially preferred in high-frequency applications. This polarizer performs polarization transformation with the irises in its structure (Chambelin & Pintos, 2006) (Tucholke, Arndt, & Wriedt, 1986).

In this study, a new polarizer is designed by adding irises on a square cross-section waveguide. At the input of the polarizer, a transition stage is designed between the WR42 waveguide and the square waveguide. At the output of the designed polarizer, a transition stage from square waveguide to circular waveguide is also designed. In the present study, it is assumed that the output of the polarizer will not be connected to a circular waveguide; it will radiate into free space serving as the feed to a reflector. Therefore, far-field simulations are carried out for the radiation pattern of the circularly polarized wave emanating from the polarizer.

Simulations are performed with a commercial electromagnetic simulation software, CST Studio Suite®. CST Studio Suite enables the solution of electromagnetic (EM) simulations using methods such as the Finite Element Method (FEM), Finite Integration Technique (FIT), and Transmission Line Matrix Method (TLM). Additional EM solvers for high-frequency applications of electrically large structures complement the general solvers. All EM solvers are based on solving Maxwell's equations by different methods. Time domain solvers use the Finite-Difference Time-Domain (FDTD) method to solve Maxwell's equations. Frequency domain solvers use the Finite Element Method (FEM) to solve Maxwell's equation. The two solvers use two different methods for the EM simulation solution of the same structure. Simulations of the iris polarizer structure are performed with the time

domain solver and the frequency domain solver independently. Therefore, the results presented here are verified by different numerical analysis methods.

The design operates dual-band within the Ka-band; more specifically at 17.2 – 21.2 GHz and 27.5 – 31 GHz frequency bands. 17.2 – 21.2 GHz and 27.5 – 31 GHz are two bands that are commonly used in receiving and transmitting circuits, respectively. A structure designed for these two bands is expected to have high return loss (>20 dB), low insertion loss (<0.2 dB), and a phase difference close to 90°. The insertion loss of the iris polarizer is less than 0.05 dB, the return loss is greater than 23 dB, and the phase difference is less than 15° around 90° for both bands. The antenna directivity of the structure with only the circular waveguide (without basic or corrugated horn) is between 8.5 and 13 dB. The side-lobe level across the band is less than -20 dB.

In this study, the design steps of the structure including the transition stages added to the input and output are given in Section 2. Electrical results and far-field simulation results of the polarizer are presented in Section 3. Conclusions and evaluations are given in Section 4.

2. IRIS POLARIZER

2.1. The Polarizer Structure

The iris polarizer contains thin metals positioned on two opposite walls of the square waveguide. These thin metals are called irises. The irises on the polarizer are shown in Figure 1.

In Figure 1, the wave at the input of the iris polarizer is a 45° tilted linearly polarized wave. When this wave is analyzed as two orthogonal (vertical and horizontal) components, the vertical component travels through the polarizer while interacting with the irises whereas the horizontal component is not affected by the irises. In other words, the irises slow down the vertical component while the horizontal component propagates as if the waveguide had no irises. The iris designs are made so that the phase difference between the vertical component and the horizontal component is 90°. Thus, a circularly polarized signal is obtained at the polarizer output. Whether

the circularly polarized signal is right-hand or left-hand depends on whether the wave at the input of the polarizer is tilted +45° or –45°, respectively. Note that the sign of the tilt angle can be controlled by the direction of the TE_{01} component.

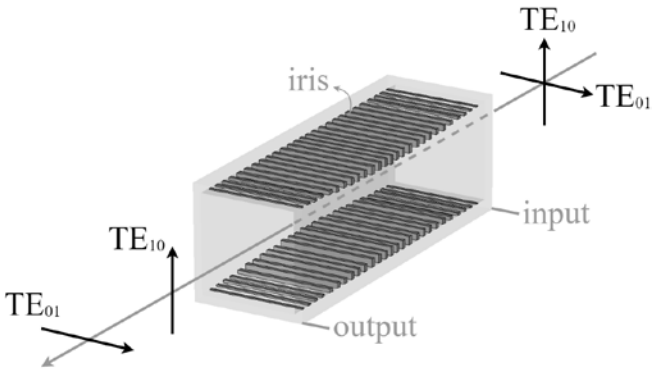

Figure 1. *The structure of the iris polarizer and polarizations at the input and output.*

2.1. Polarizer Design

Iris polarizer design consists of the design of two components: the square waveguide and irises. The square waveguide dimensions are calculated depending on the frequency band. For a rectangular waveguide, the dimensions are calculated depending on the cut-off frequency (Pozar, 2004):

$$f_{c,mn} = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \quad (1)$$

where $f_{c,mn}$ is the cut-off frequency, m and n are the modes, a and b are the dimensions of the waveguide. m and n can have values 0,1,2,3... . For a square waveguide $a = b$. For TE_{10} and TE_{01} modes, mn is calculated by taking 10 or 01. For 17.2-21.2 GHz and 27.5-31 GHz frequency bands, the cut-off frequency is 13 GHz. In this design, the size of the square waveguide is calculated as 11.75 mm. With this size, the next higher-order mode is TE11 with a cut-off frequency of 37.46 GHz. Since the design operates in dual-band, the size of the waveguide is selected larger than the standard waveguide. The size of the iris is of great importance for achieving return loss, low insertion loss, and a phase difference close to 90° in dual-

band. In this design, the number of irises, thickness, height, width, and spacing between irises are calculated. Then the structure is fine-tuned to improve its performance in dual band. The thickness of the iris, *t*, the space between the irises, *g*, the iris height, *h*, and the number of irises are other design parameters. Figure 2 shows the iris parameters on the polarizer.

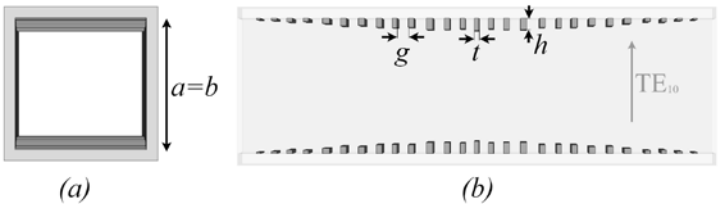

Figure 2. *Geometry of iris polarizer (a) front view, (b) side view.*

For the phase difference between the vertical and horizontal components of the linearly polarized wave at the input of the polarizer to be 90° at the output, the vertical component has to be delayed by the extra path provided by the irises. Therefore, each of the iris parameters is of great importance to provide the phase difference. While achieving this goal, the return loss must be low and the signal transmission must be high. Iris thickness (t) is the parameter that directly affects the phase difference. In the design, the initial value of each iris thickness is calculated as follows (Hwang & Lee, 2014):

$$t = 0.15\lambda_m \tag{2}$$

where λ_m is the guided wavelength at the center frequency. Optimization is performed to fine-tune the phase difference in dual-band applications. As a result of the optimization, the iris thicknesses in the design vary between $0.34 - 0.6$ mm. The gap between the irises is also a parameter that directly affects the phase difference. The best electrical results are obtained when the gap next to each iris is at least twice the thickness of the iris:

$$g > 2t \tag{3}$$

As a result of the optimization, the iris gaps in the design vary between $0.82 - 1.63$ mm. Another important design parameter is the height of each iris. The iris height significantly affects the phase difference as well as the return loss. Considering the polarizer structure, the height of the iris increases from one end to the center of the polarizer and decreases symmetrically from the center of the polarizer to the other end. Since the return loss is inversely proportional to the height of the front iris, using this configuration increases the return loss by decreasing the height of the front iris. The following range is used for iris heights:

$$h = (0.01 - 0.1)\lambda_m \quad (4)$$

As a result of the optimization, the iris heights in the design vary between $0.12 - 1.06$ mm. The number of irises in the polarizer also affects the phase difference. The number of irises can be increased so that the output phase difference between the wave components is close to 90° throughout the desired band. The number of irises can be odd or even (Hwang & Lee, 2014). This study is initially designed with 23 irises. However, 23 irises are not enough for a phase difference close to 90° in dual-band. As a result of the simulations, the number of irises is increased to 27.

Table 1. *Dimensions of the irises after optimization.*

Parameter	**Dimension (mm)**	**Parameter**	**Dimension (mm)**	**Parameter**	**Dimension (mm)**
t_0	0.41	g_0	0.	h_0	1.06
t_1	0.44	g_1	0.82	h_1	0.91
t_2	0.49	g_2	0.88	h_2	0.96
t_3	0.55	g_3	0.98	h_3	0.98
t_4	0.49	g_4	1.1	h_4	0.78
t_5	0.44	g_5	0.98	h_5	0.82
t_6	0.51	g_6	0.88	h_6	0.77
t_7	0.53	g_7	1.02	h_7	0.61
t_8	0.49	g_8	1.06	h_8	0.65
t_9	0.6	g_9	0.98	h_9	0.45
t_{10}	0.48	g_{10}	1.2	h_{10}	0.28
t_{11}	0.45	g_{11}	0.96	h_{11}	0.30
t_{12}	0.48	g_{12}	0.9	h_{12}	0.28
t_{13}	0.34	g_{13}	0.96	h_{13}	0.12

The irises on the two opposite walls of the polarizer are symmetrically designed. There is one iris in the center of the wall of the polarizer and 13 symmetrical irises on either side of the center iris. The iris in the center is called the 0th iris. The iris numbers continue to increase from the center to the end of the polarizer. The final values of t, g, and h for each iris are given in Table 1.

2.2. The Transition Sections

The iris polarizer is designed to be used in the feed structure of an antenna system. Therefore, a circular transition is designed at the output of the polarizer which supports circular polarization. The circular waveguide can be used as a feed by adding a basic or corrugated horn aperture. The radius r of the circular waveguide is calculated for the cut-off frequency $f_{c,mn}$ by the equation (Pozar, 2004):

$$f_{c,mn} = \frac{p'_{nm}}{2\pi r\sqrt{\mu\varepsilon}} \tag{5}$$

where nm indicates the mode and p'_{nm} value is 3.83 for TE_{01} mode. In this design, the radius of the circular waveguide is determined as 7 mm as a result of calculations and simulations. The cut-off frequency for the next higher mode (TE_{11}) is calculated to be 37.46 GHz. A loft structure is used between the circular waveguide and the square polarizer. The circular transition structure is shown in Figure 3. As a result of the simulations, the length of the loft structure and the waveguide are 12 mm and 10 mm respectively.

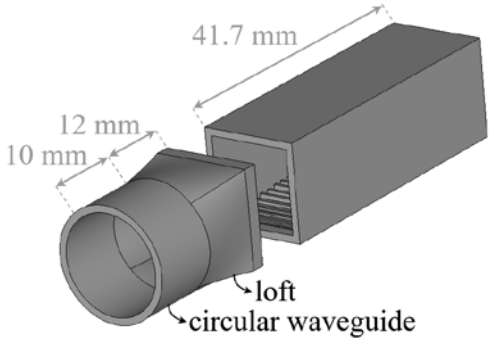

Figure 3. *Iris polarizer and circular transition.*

The input of the polarizer is a square waveguide and does not conform to standard waveguide dimensions. A transition is used to convert this input to standard dimensions. One end of the rectangular transition is a square waveguide, and the other end is a WR42 waveguide with a loft structure between them. The WR42 waveguide is designed at an angle of 45° to the vertical so that the wave arrives tilted at ±45° to the input of the polarizer. Therefore, TE_{10} mode from WR42 is converted as RHCP wave to the other end of the polarizer, while TE_{01} mode is converted as LHCP wave. Figure 4 shows the polarizer and transition sections. As a result of the simulations, the length of the loft structure and the waveguide are determined as 20 mm and 10 mm, respectively.

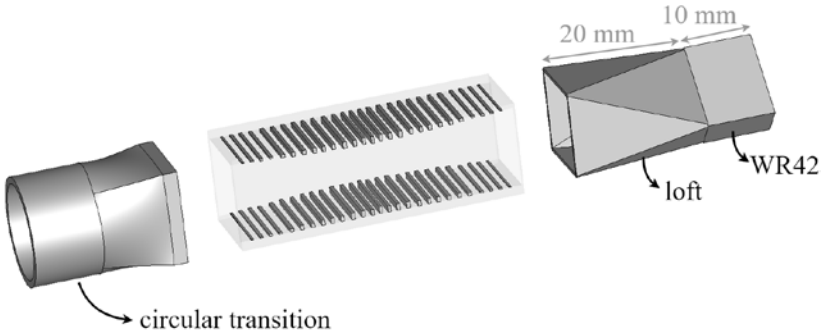

Figure 4. *Iris polarizer and transition sections.*

3. SIMULATIONS

The analysis and simulations of the dual-band (17.2-21.2 GHz and 27.5-31 GHz) polarizer and transition sections are carried out with the commercial electromagnetic simulation software, CST Studio Suite. The analyses are carried out in two steps. In the first step, the S parameters are calculated *for each mode* from the WR42 input (port 1) to the end of the square polarizer section (port 2). The circular transition is not included in this first analysis because the output from the circular section is not intended as a waveguide port; it is rather conceived as the feed aperture for the reflector antenna. Therefore, in the second part of the analysis, the whole structure including the circular transition section is analyzed as an antenna with a single port, and its radiation characteristics are studied.

Hence, firstly, the performance of the polarizer and the rectangular transition is analyzed. On the polarizer, 27 irises are used on each wall. A rectangular transition section is used to ensure that the signal arrives at ±45° to the iris input. The rectangular waveguide is defined as port 1 and the output of the polarizer is defined as port 2. The reflection and transmission coefficients between the two modes at port 1 and the two modes at port 2 are analyzed. The return loss and insertion loss of the structure are given in Figure 5. The two bands of interest are marked with green in both figures. It is seen that the return loss is greater than 30 dB from 17.7 to 21.2 GHz, but the return loss is 23 dB from 27.5 to 31 GHz. Better return loss values are achieved in port 1 where the waveguide transition section exists. In port 2, there is no transition section. Therefore, the irises stand close to the port and there is not much space for the evanescent modes to fade away. Hence, a higher S22 is not surprising and better performance is expected in the presence of the circular transition section. The transmission between the ports is also very well with an insertion loss less than 0.05 dB throughout the two bands. Note that the S21 values are given separately for both modes. This is important because each mode (vertical and horizontal) experience different electrical paths and although even if the phase difference between them turns out to be 90° a difference between the insertion losses will mean deviation from circular polarization. With this perspective, the largest difference of 0.035 dB between the two modes causes only 0.8% deviation in the axial ratio of the circular polarization which is more than acceptable.

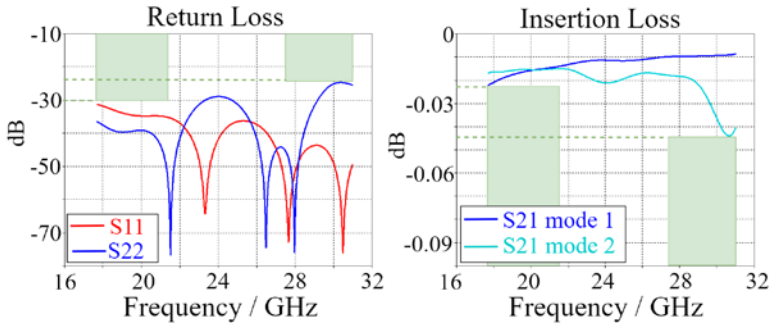

Figure 5. *Return and insertion losses for the polarizer and rectangular transition.*

The phase difference between the vertical component and the horizontal component of the wave should be approximately 90° at the end of the polarizer. In dual-band structures, it is difficult to set the phase difference to 90° throughout the operation bands. The initial goal of the present study was to achieve a phase deviation of 15°. The phase difference of the resulting structure is given in Figure 6. It is seen that the phase-difference along both bands is tuned around 90° the goal of 15° deviation is achieved with values ranging between 83° and 98°.

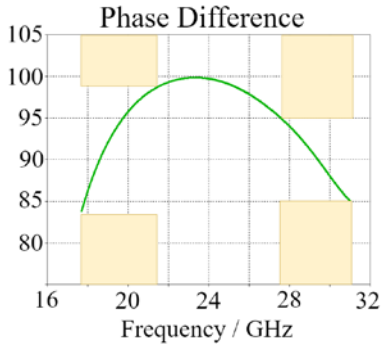

Figure 6. *Phase difference between the vertical and horizontal wave components at the output.*

The performance results of the iris polarizer are also presented in Table 2. The electrical performances of this study and other polarizer studies in close frequency bands are compared in Table 3. Note that although the literature values for the return loss and phase difference are better, the present study covers a much larger frequency range (f_{max} / f_{min} = 31/17.7 = 1.75) compared to <1.53 in the literature.

Table 2. *Electrical performance of the iris polarizer and rectangular transition.*

Frequency (GHz)	**Minimum Return Loss (dB)**	**Phase Difference Range (°)**
17.7 – 21.2	30	83 – 98
27.5 – 31	23	85 – 95

Table 3. *Comparison of the electrical performance.*

	Frequency (GHz)	**Minimum Return Loss (dB)**	**Phase Difference Range (°)**
This Study	17.2 – 21.2 27.5 – 31	23	83 – 98
(Hwang & Lee, 2014)	20.8 – 21.2 30.6 – 31	30	86 – 90
(Leal-Sevillano, Ruiz-Cruz, Montejo-Garai, & Rebollar, 2013)	19.75 – 20.25 29.75 – 30.25	27	89 – 91
(Liu, Li, Li, & He, 2008)	24 – 36	27	82 – 98

In the second stage of the analysis, the circular waveguide transition section at the output of the iris polarizer structure is included. Far-field (antenna) simulation results of the structure are analyzed. The return loss of the structure is seen to be greater than 32 dB in Figure 7. A return loss higher than 32 dB means that 99.937% of the energy that enters the polarizer is radiated into the free space through the circular end, which is a very good figure of efficiency. The far-field pattern is shown in Figure 8. The rotational symmetry of the radiation pattern indicates that the axial ratio of the electric field at the aperture is around unity. The side-lobe value of the structure over the entire frequency band is around -20 dB.

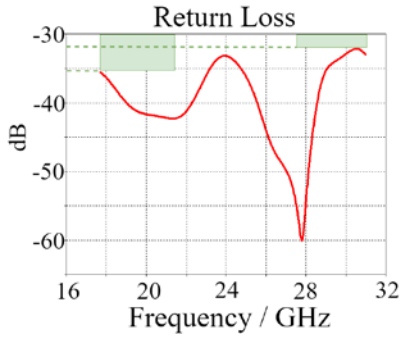

Figure 7. *Return loss of all structure.*

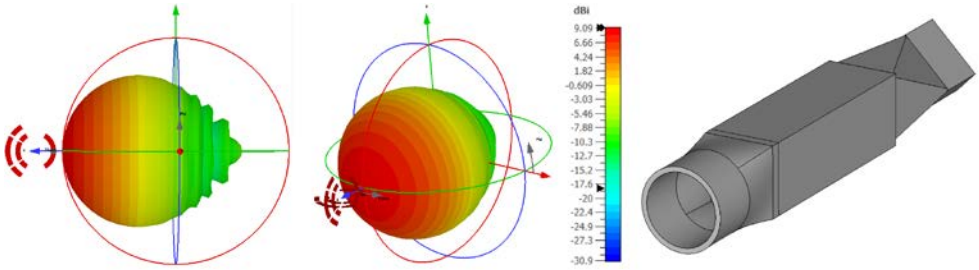

Figure 8. *Far-field pattern of the iris polarizer and transitions.*

Figure 9 shows the electric field distribution of the structure consisting of the iris polarizer and the circular waveguide. From the input of the iris polarizer to the end of the circular waveguide, the signal changes from linearly polarized to circularly polarized.

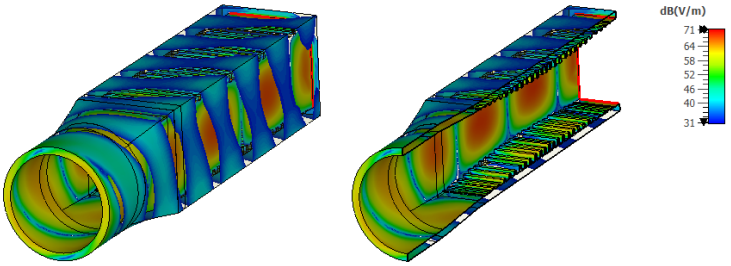

Figure 9. *Simulated electric field distribution of the iris polarizer and circular waveguide*

The directivity and realized gain of the structure over the full frequency band are given in Figure 10. The gain is above 8.5 dB which is satisfactory for the dish that the polarizer is intended to feed.

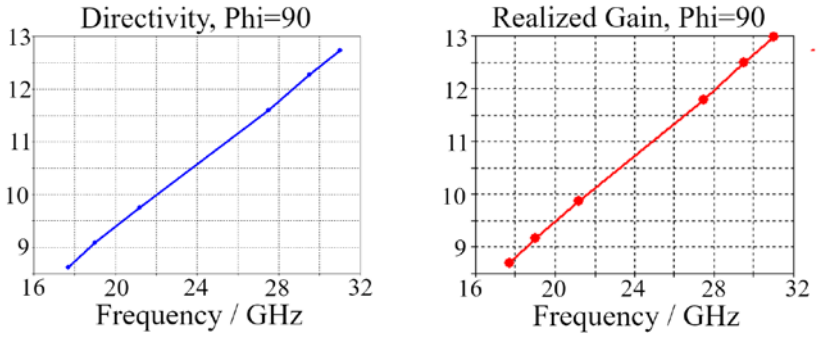

Figure 10. *Directivity (dBi) and realized gain (dBi) of the design for all frequency ranges.*

4. CONCLUSION

In this paper, the design and optimization results of a dual-band iris polarizer with transition sections are presented. The design works within the Ka-band, specifically at the 17.2 – 21.2 GHz and 27.5 – 31 GHz frequency bands. The iris polarizer structure consists of 27×2 irises on two opposite walls on the square waveguide. The irises create a delay on the vertical component of the ±45° tilted linearly polarized signal at the input of the polarizer. Thus, the signal arrives at the end of the polarizer as either a RHCP or LHCP wave. WR42 to square transition is added to the input of the polarizer. At the output of the polarizer, a transition from square waveguide to circular waveguide is designed. The insertion loss of the iris polarizer is <0.05 dB, the return loss is >23 dB, and the phase difference variation between the two linear components of the output wave is less than 15° around 90° for both bands. Far-field results are obtained with a circular aperture at the output of the polarizer structure. Directivity increases linearly with increasing frequency and the side lobe levels are around -20 dB.

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Electrical-Electronics Engineering/Elektrik-Elektronik Mühendisliği

BOOK REVIEW

BALANIS' ADVANCED ENGINEERING ELECTROMAGNETICS, 3RD EDITION [BOOK REVIEW]

Fatih ERDEN

National Defence University, Department of Electronics Engineering, Istanbul, Turkey, ferden@dho.edu.tr

ABSTRACT

The third edition of "Balanis' Advanced Engineering Electromagnetics" marks a significant advancement in the field of electromagnetics education and research. This edition not only retains the foundational theories of its predecessors but also introduces cutting-edge topics like artificial impedance surfaces, offering a comprehensive overview of contemporary electromagnetic technologies. With its detailed coverage of advanced topics such as metasurfaces, radar cross-section reduction, and optimization of antenna parameters, the book stands as an indispensable resource for students and professionals in electrical engineering. It bridges theoretical concepts with practical applications, making it an essential tool for both teaching and research.

Keywords: *Electromagnetics, artificial impedance surfaces, metasurfaces, antenna optimization, radar cross-section reduction.*

BALANIS'İN İLERİ MÜHENDİSLİK ELEKTROMANYETİĞİ, 3. BASKI [KİTAP İNCELEMESİ]

ÖZ

"Advanced Engineering Electromagnetics" adlı kitabın üçüncü baskısı, elektromanyetik eğitim ve araştırma alanında önemli ilerlemeleri sergilemektedir. Bu baskı, seleflerinin temel taslaklarını ve teorik içeriklerini korumanın yanı sıra yapay empedans yüzeyleri gibi en modern konuları tanıtarak, en yeni elektromanyetik teknolojileri kapsamlı bir şekilde sunmaktadır. Teorik kavramları pratik uygulamalarla birleştiren bu kitap, metayüzeyler, radar kesit alanı azaltma ve anten parametrelerinin optimizasyonu gibi ileri düzey konuların ayrıntılı bir şekilde ele alınmasıyla, elektrik ve elektronik mühendisliği öğrencileri ve araştırmacıları için vazgeçilmez bir kaynak olmaya devam edecektir.

Anahtar Kelimeler: *Elektromanyetik, yapay empedans yüzeyleri, metayüzeyler, anten optimizasyonu, radar kesit alanı azaltma.*

1. INTRODUCTION

"*Advanced Engineering Electromagnetics*" by Constantine A. Balanis has been a cornerstone in the field of electromagnetics since its first edition in 1989. The book has significantly contributed to electromagnetics education from undergraduate to graduate levels and in various research activities across a wide spectrum of the field. Its evolution reflects the dynamic changes and advancements in the world of electromagnetics.

The third edition of "*Balanis' Advanced Engineering Electromagnetics*," (Balanis, 2024), set for release in electronic and hard copy formats in January or February 2024, has completed its design and production stages and is currently in the final phase of collective printing. This edition, which I had the privilege of reviewing thanks to the materials provided by Professor Balanis and my involvement in the translation of the second edition to Turkish (Balanis, 2021a), upholds the foundational strengths of the previous editions and incorporates substantial advancements. Among these is a new chapter on artificial impedance surfaces (AIS), highlighting current and advanced electromagnetic technologies, including metasurfaces. This book review aims to explore the technical enhancements and educational significance of the third edition, underlining its importance in both naval and civilian electrical engineering education.

Electromagnetic theory, central to electrical engineering and physics, plays a crucial role in the understanding and designing of systems involving antennas, microwave circuits, radio frequency and optical communications, wireless technologies, etc. This review evaluates the third edition's expanded scope and modernized approach, emphasizing its significance in electromagnetic research and education.

2. EVOLUTION AND CONTENT OF EDITIONS

2.1. First Edition (1989)

The first edition was a welcome addition to graduate electromagnetic theory courses, suitable for a two-semester course. It included fundamental theory which can be found in many classic texts, along with canonical examples like modes in waveguides and scattering from circular cylinders. The book was praised for its readability, coherence,

and the inclusion of contemporary material (Glisson, 1989). Chapters 8-11 provided a balance of classical examples and contemporary applications, relevant to integrated and fiber optics. Modern numerical and asymptotic techniques were introduced in Chapters 12 and 13, marking significant differences from older electromagnetic texts.

2.2. Second Edition (2012)

The second edition marked a significant enhancement of the book's content, introducing innovative elements and the developments in the field (Orlandi, 2015). A key addition was a new chapter on diffraction by a wedge with impedance surfaces, providing an in-depth exploration of this complex topic. The edition also introduced an insightful section on double negative (DNG) metamaterials, exploring the unique properties and applications of these materials with negative refractive indices. Further enriching the book was the inclusion of a section on artificial impedance surfaces, including artificial magnetic conductors (AMC), electromagnetic band gap (EBG), and photonic band gap (PBG) structures. This section, outlined in Section 8.8 of the Second Edition, delved into various applications and the evolving role of these surfaces, a topic not covered in the first edition. Additionally, the second edition was updated with numerous new figures, photos, tables, and end-of-chapter problems, enhancing the reader's learning experience.

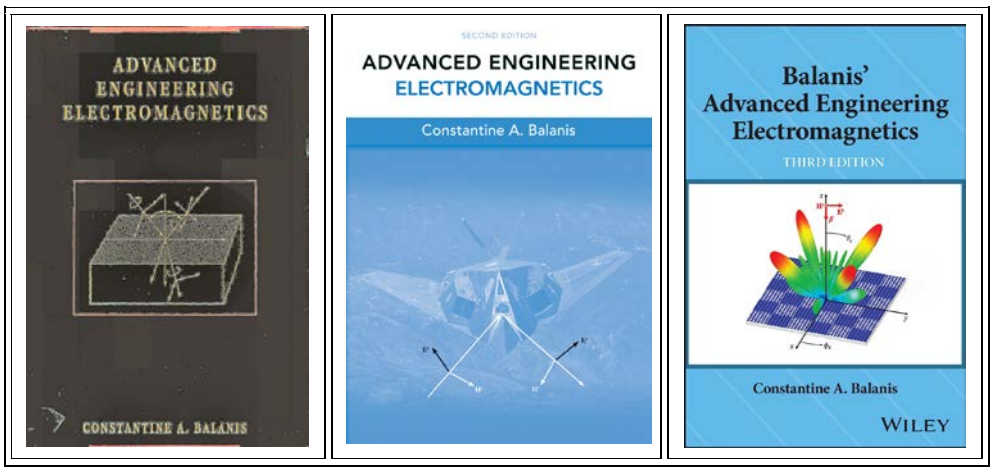

Figure 1. *The Evolution of Advanced Engineering Electromagnetics: 1st Edition, 2nd Edition, 3rd Edition.*

2.3. Third Edition (Early 2024)

The third edition (Balanis, 2024), represents a significant step forward in the evolution of the text. This edition not only preserves the comprehensive approach of its predecessors but also integrates cutting-edge advancements in electromagnetic technologies. A noteworthy highlight is the inclusion of a new chapter, Chapter 16, dedicated to artificial impedance surfaces (AIS). This chapter provides a deep dive into metasurfaces, focusing on their application in controlling radar cross-section and optimizing antenna parameters.

Contents of the 3rd Edition:

1. Time-Varying and Time-Harmonic Electromagnetic Fields
2. Electrical Properties of Matter
3. Wave Equation and Its Solutions
4. Wave Propagation and Polarization
5. Reflection and Transmission
6. Auxiliary Vector Potentials, Construction of Solutions, and Radiation and Scattering Equations
7. Electromagnetic Theorems and Principles
8. Rectangular Cross-Section Waveguides and Cavities
9. Circular Cross-Section Waveguides and Cavities
10. Spherical Transmission Lines and Cavities
11. Scattering
12. Integral Equations and the Moment Method
13. Geometrical Theory of Diffraction
14. Diffraction by a Wedge with Impedance Surfaces
15. Green’s Functions
16. Artificial Impedance Surfaces

The third edition enhances the reader's learning experience by including over 4,500 PowerPoint slides and 53 MATLAB programs, which cover computations, graphical visualizations, and animations, particularly focusing on the design of checkerboard metasurfaces for RCS reduction and metasurface printed antennas. These resources are invaluable for both teaching and self-study.

Chapter 16: Artificial Impedance Surfaces offers an in-depth exploration of AIS and their diverse applications, focusing on the control and broadband RCS reduction using checkerboard designs, as well as optimizing antenna fundamental parameters like input impedance, directivity, realized gain, and amplitude radiation pattern. This chapter delves into the practical applications and theoretical aspects of AIS, including the study of leaky-wave antennas utilizing 1-D and 2-D polarization diverse-holographic high impedance metasurfaces for advanced radiation control and optimization. It extensively covers applications in various antenna types such as monopole, horizontal dipole, circular loop, aperture antenna, microstrip array, and surface-wave antennas, emphasizing their use in high-gain printed leaky-wave antennas. These topics not only underscore the theoretical aspects but also provide practical application perspectives, making the book an essential resource for advanced studies.

Chapter 16: Artificial Impedance Surfaces Overview:

3. COMMENTS

3.1. Personal Reflections

Advanced Engineering Electromagnetics has significantly influenced my academic path since 2001. It has consistently featured in my teaching modules, owing to its thorough treatment of electromagnetic engineering topics.

My interaction with Professor Balanis at the AP/S-URSI 2023 symposium was enlightening. We discussed the impact of his book and its Turkish translation, a project I contributed to as part of a team of Turkish academicians and researchers (Balanis, 2021b). Balanis expressed appreciation for our translation efforts and further supported our endeavors by generously providing additional materials for teaching and research, underscoring his dedication to the field of electromagnetics education.

3.2. The Book’s Impact on Electromagnetics Education

The book's impact is evident in its over 13,000 citations in scientific articles, emphasizing its role as a primary reference in graduate-level electromagnetics education. It's particularly useful in electrical engineering, covering a broad range of topics relevant to modern naval and civilian electromagnetics applications.

4. CONCLUSION

Reflecting on Balanis' journey from Greece to the USA (Balanis, 2023), one can't help but be inspired by his indelible mark on electromagnetics and antenna theory, significantly impacting electromagnetic research and education. The upcoming AP/S-URSI 2024 symposium (IEEE AP-S/URSI, 2024), which will honor Professor Balanis on his 85th birthday, is a testament to his ongoing influence in the field.

The third edition of his book, with its focus on emerging technologies like artificial impedance surfaces, ensures its continued relevance in a technologically evolving world. It's more than an update; it represents Balanis' lifelong commitment to advancing electromagnetic education and research, making it an essential resource for students and researchers in advanced engineering electromagnetics.

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Address:
Assoc.Prof.Dr. Fatih ERDEN
National Defence University (Milli Savunma Üniversitesi)
Turkish Naval Academy (Deniz Harp Okulu Dekanlığı)
34942 Tuzla/İstanbul/Türkiye

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Adres:
Doç.Dr. Fatih ERDEN
Deniz Harp Okulu Dekanlığı
34942 Tuzla/ İstanbul/Türkiye

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-Authors have the responsibility of responding to the reviewers' comments promptly and cooperatively, in a point-by-point manner.

The Responsibilities of the Reviewers:

-Peer review process has two fundamental purposes as follow: The first purpose is to decide whether the relevant article can be published in JNSE or not and the second purpose is to contribute to the improvement of the weaknesses of the related article before the publication.

-The peer review process for an article to the JNSE consists of a double-blind review, which means that both the reviewer and author identities are concealed from the reviewers, and vice versa, throughout the review process. Reviewed articles are treated confidentially in JNSE.

-Reviewers must respect the confidentiality of peer review process.

-Reviewers must refrain from using the knowledge that they have obtained during the peer review process for their own or others' interests.

-Reviewers should definitely be in contact with the JNSE if they suspect about the identity of the author(s) during the review process and if they think that this knowledge may raise potential competition or conflict of interest.

-Reviewers should notify the JNSE in case of any suspicion regarding the potential competition or conflict of interest during the review process.

-Reviewers should accept to review the studies in which they have the required expertise to conduct an appropriate appraisal, they can comply with the confidentiality of the double-blind review system and that they can keep the details about the peer review process in confidential.

-Reviewers should be in contact with the JNSE in order to demand some missing documents, following the examination of the article, supplementary files and ancillary materials.

-Reviewers should act with the awareness that they are the most basic determinants of the academic quality of the articles to be published in the journal and they should review the article with the responsibility to increase academic quality.

-Reviewers should be in contact with the JNSE editors if they detect any irregularities with respect to the Ethical Principles and Publication Policy.

-Reviewers should review the articles within the time that has been allowed. If they can not review the article within a reasonable time-frame, then they should notify the journal as soon as possible.

-Reviewers should report their opinions and suggestions in terms of acceptance / revision / rejection for the manuscript in the peer review process through the Referee Review Form which is provided by JNSE.

-In case of rejection, reviewers should demonstrate the deficient and defective issues about the manuscript in a clear and concrete manner in the provided Referee Review Form.

-Review reports should be prepared and submitted in accordance with the format and content of the Referee Review Form which is provided by JNSE.

-Review reports should be fair, objective, original and prudent manner.

-Review reports should contain constructive criticism and suggestions about the relevant article.

The Responsibilities of the Editors:

-Editors are responsible of enhancing the quality of the journal and supporting the authors in their effort to produce high quality research. Under no conditions do they allow plagiarism or scientific misconduct.

-Editors ensure that all submissions go through a double-blind review and other editorial procedures. All submissions are subject to a double-blind peer-review process and an editorial decision based on objective judgment.

-Each submission is assessed by the editor for suitability in the JNSE and then, sent to the at least two expert reviewers.

-Editors are responsible for seeking reviewers who do not have conflict of interest with the authors. A double-blind review assists the editor in making editorial decisions.

-Editors ensure that all the submitted studies have passed initial screening, plagiarism check, review and editing. In case the editors become aware of alleged or proven scientific misconduct, they can take the necessary steps. The editors have the right to retract an article. The editors are willing to publish errata, retractions or apologies when needed.

Etik İlkeler ve Yayın Politikası

Deniz Bilimleri ve Mühendisliği Dergisi (Bundan sonra DBMD olarak anılacaktır.); uluslararası düzeyde, hakemli, çok disiplinli, 2003 yılından bu yana yılda iki kez yayınlanan, bilim ve teknoloji dergisidir. DBMD yayın etiğinde en yüksek standartların, editoryal ve hakemlik süreçlerinin kilit unsuru olarak değerlendirildiği bir platform sunmayı taahhüt etmektedir.

DBMD'ne gönderilen her bir makale için değerlendirme sürecinde çift-kör hakemlik sistemi uygulanmaktadır. Buna göre, değerlendirme süreci boyunca hakem ve yazarlar birbirlerinin bilgilerini görememektedir. Dergiye gönderilen çalışmaların yazar-hakem ve hakem-yazar açısından süreçlerinde gizlilik esastır. DBMD'ne gönderilen makalelerin değerlendirme sürecindeki inceleme aşamasında kabul edilmeleri halinde, ilgili makaleler için düzenleme aşamasına geçilmektedir. Düzenleme aşamasında, ilgili makaleler yazım formatı ve dilbilgisel yönlerden incelenir. Makalelerin sayfalar üzerindeki biçimi ve yerleşimleri kontrol edilip düzenlenir. Ayrıca referans kontrolü yapılır. DBMD'nde kontrol edilen ve düzenlenen makaleler gizli tutulmaktadır.

DBMD'ne gönderilen makaleler, Yayın Kuralları sayfasında belirtilen kriterlere ilişkin, intihal tespit programı aracılığıyla kontrol edilir. Editörler, kanıtlanmış bir bilimsel kötü kullanımdan ya da usulsüzlükten haberdar olurlarsa bu konuda gerekli adımları atabilirler. Bu anlamda, Editörler gerekli durumlarda DBMD'ne gönderilen ya da DBMD'nde yayınlanmış makaleleri geri çekme hakkına sahiptir.

Düzenleme aşamasının başarılı olarak sonuçlanmasını takiben, ilgili makaleler DBMD'nin bir sayısında yayınlanmak üzere saklı tutulur ve kayıt altına alınır. DBMD'ne yayınlanmak üzere gönderilen makaleler; yazılı materyal gönderme, işleme ve yayınlama süreçlerindeki tüm ücretlerden muaf tutulmaktadır. DBMD'nde yayınlanmak üzere kabul edilen makaleler, derginin internet sitesinden çevrimiçi olarak ücretsiz bir şekilde yayınlanır ve basılır. Dergide yayınlanması kabul edilen çalışmalar, derginin web sitesinden açık erişim ile erişilebilir kılınmıştır. Dergi ayrıca, Milli Savunma Üniversitesi, Deniz Harp Okulu Matbaası tarafından basılmaktadır.

DBMD; editörü ve en az beş değişik üniversitenin öğretim üyelerinden oluşmuş danışman grubu ile açık erişim politikasını benimsemektedir. Buna göre, tüm içerikler ücretsiz olarak kullanıcılar veya kurumlar için ulaşılabilirdir. Kullanıcıların DBMD bünyesindeki makalelerin tam metinlerini okuma, indirme, kopyalama, dağıtma, yazdırma, arama veya bunlara bağlantı verme ve diğer yasal araştırma amaçları için kullanma hakları saklı tutulmaktadır.

DBMD'nin yayın etiği, temel olarak Yayın Etiği Komitesi (COPE), Dünya Mühendislik Kuruluşları Federasyonu (WFEO), Bilim Kurulu Editörleri (CSE) ve Elsevier'in Editörler için Yayın Etiği açıklamaları kapsamında yayınlanmış yönergelere ve önerilere dayanmaktadır.

Editörler, yazarlar ve diğer taraflar da dâhil edilebilecek şekilde yayın sürecindeki görev ve sorumluluklar aşağıdaki gibi tanımlanmıştır.

Yazarların Sorumlulukları:

-Yazarlar, dergide yayınlanan makalelerinin bilimsel, bağlamsal ve dilsel yönlerinden sorumlu tutulmaktadır. Dergide ifade edilen veya ima edilen görüşler, aksi belirtilmediği sürece, Enstitünün resmi görüşü olarak yorumlanamaz ve yansıtılamaz.

-Yazarlar çalışmalarında, DBMD'nin DergiPark internet sayfasında yer alan "Yazım Kuralları"nı dikkate almalıdır.

-Yazarlar araştırmalarını etik ve sorumlu bir şekilde yürütmeli ve ilgili tüm mevzuatları takip etmelidir.

-Yazarlar çalışmaları ve yayınlarının içeriği için ortak sorumluluk almalıdır.

-Yazarlar, yöntemlerin ve bulguların doğru bir şekilde raporlandığından emin olmak için yayınlarını her aşamada dikkatlice kontrol etmelidir.

-Yazarlar, başkalarına ait çalışmaları dolaylı alıntı, doğrudan alıntı ve referanslar ile doğru bir şekilde göstermelidir. Yazarlar, makalelerindeki fikirlerin şekillendirilmesinde etkili ya da bilgilendirici olmuş her türlü kaynağa referans vermelidir.

-Yazarlar çalışmalarındaki hesaplamaları, ispatları, veri sunumlarını ve yazı tiplerini dikkatlice kontrol etmelidir.

-Yazarlar çalışmalarının sonuçlarını dürüstçe; uydurma, çarpıtma, tahrifat veya uygunsuz manipülasyona yer vermeden sunmalıdır. Çalışmalardaki görsel kaynaklar yanıltıcı bir şekilde değiştirilmemelidir.

-Yazarlar, çalışmalarındaki bulguları açık ve net bir şekilde sunmak için araştırma yöntemlerini tanımlamalı ve paylaşmalıdır.

-Yazarlar, yayınlanmış makalelerinin telif haklarını DBMD yayıncısına devrettiklerini kabul etmektedir.

-Yazarlar çalışmalarına çeşitli görsel kaynakları, figürleri, şekilleri vb. dahil etmek için gerekli izinleri almakla yükümlüdür. İlgili çalışmada yer alması gereken resim, şekil vb. anlatımı destekleyici materyaller için gerekli kişilerden ya da kurumlardan izin alınması yazarın sorumluluğundadır.

-Çok yazarlı yayınlarda -aksi belirtilmedikçe- yazar sıralamaları sunulan katkılara göre yapılmalıdır.

-Yazarlar gönderdikleri çalışmada herhangi bir hata tespit ederlerse bu konuda derhal editörü uyarmalıdır.

-Yazarlar dergiye gönderdikleri makalelerin başka bir yerde yayımlanmamış ya da yayımlanmak üzere gönderilmemiş olmaları ile ilgili DBMD'nin DergiPark internet sayfasında yer alan "Yayın Kuralları"nı dikkate almalıdır.

-Yazarlar, ilgili çalışmaları DBMD'nde yayınlandıktan sonra hata tespit ederlerse bu konuda gerekli düzeltmelerin yapılabilmesi amacıyla derhal editör veya yayıncı ile iletişime geçip onlar ile birlikte çalışmalıdır.

-İlgili çalışmada, doğası gereği kullanımlarında olağandışı tehlikeler barındıran çeşitli kimyasallar veya ekipmanlardan yararlanılmış ise yazarların tüm bunları çalışmasında açıkça belirtmesi ve tanımlaması gerekmektedir.

-İnsanlar ve hayvanların katılımını gerektiren çalışmalar için, yazarlar tüm sürecin ilgili yasalara ve kurumsal yönergelere uygun olarak gerçekleştirildiğinden emin olmalıdır ve ilgili komitelerden etik onay alındığını çalışmalarında açık bir şekilde ifade edip belgelendirmelidir.

-İnsanların katılımını gerektiren çalışmalar için, yazarlar kurumsal etik kurul onayı almakla yükümlüdürler. Yazarlar, katılımcıların süreç ile ilgili olarak bilgilendirildiklerini ve bu anlamda, katılımcılardan gerekli izinlerin alındığını bildirmek ve belgelemek zorundadır. Yazarlar, katılımcıların haklarının gözetildiğini açıklayan açık bir bildirim sunmalıdır. Ayrıca bu süreçte, katılımcıların gizlilik hakları her zaman korunmalıdır.

-Yazarlar, hakemlerin değerlendirmelerini, yorumlarını ve eleştirilerini zamanında ve işbirliği içerisinde dikkate almalıdır ve bu konuda, gerekli güncellemeleri yapmalıdır.

Hakemlerin Sorumlulukları:

-Hakem değerlendirme sürecinin iki temel amacı vardır: İlk amaç, ilgili makalenin DBMD'nde yayınlanıp yayınlanamayacağına karar vermektir ve ikinci amaç, yayından önce ilgili makalenin eksik yönlerinin geliştirilmesine katkıda bulunmaktır.

-DBMD'ne gönderilen her bir makale için değerlendirme sürecinde çift-kör hakemlik sistemi uygulanmaktadır. Buna göre, değerlendirme süreci boyunca hakem ve yazarlar birbirlerinin bilgilerini görememektedir. Dergiye gönderilen çalışmaların yazar-hakem ve hakem-yazar açısından süreçlerinde gizlilik esastır.

-Hakemler, değerlendirme sürecinin gizliliğine saygı göstermelidir.

-Hakemler, değerlendirme sürecinde elde ettikleri bilgileri kendilerinin veya başkalarının çıkarları için kullanmaktan kaçınmalıdır.

-Hakemler, değerlendirme sürecinde yazar(lar)ın kimliğinden şüphe etmeleri ve bu bilginin herhangi bir potansiyel rekabet veya çıkar çatışması yaratacağını düşünmeleri halinde mutlaka DBMD ile iletişime geçmelidir.

-Hakemler, değerlendirme sürecinde şüphe ettikleri potansiyel rekabet veya çıkar çatışması durumlarını DBMD'ne bildirmelidir.

-Hakemler, uygun bir değerlendirme yapabilmek için gereken uzmanlığa sahip oldukları, çift-kör hakemlik sisteminin gizliliğine riayet edebilecekleri ve değerlendirme süreci ile ilgili detayları gizli tutabilecekleri çalışmaların hakemliğini kabul etmelidir.

-Hakemler makaleyi, ek dosyaları ve yardımcı materyalleri incelemelerini takiben bazı eksik belgelere ihtiyaç duymaları halinde bunları talep etmek üzere DBMD ile iletişime geçmelidir.

-Hakemler dergide yayınlanacak makalelerin akademik kalitesinin en temel tespit edicisi olduklarının bilinciyle davranmalı ve akademik kaliteyi arttırma sorumluluğuyla inceleme yapmalıdır.

-Hakemler, Etik İlkeler ve Yayın Politikası ile ilgili herhangi bir usulsüzlük tespit etmeleri halinde DBMD editörleri ile irtibata geçmelidir.

-Hakemler, kendilerine tanınan süre içerisinde makaleleri değerlendirmelidir. Şayet uygun bir zaman içerisinde değerlendirme yapamayacaklarsa, bu durumu en kısa zamanda DBMD'ne bildirmelidirler.

-Hakemler, değerlendirme sürecindeki çalışma için kabul etme / yeniden gözden geçirme / reddetme şeklindeki önerilerini DBMD tarafından sağlanan Hakem Değerlendirme Formu aracılığıyla bildirmelidir.

-Sonucu reddetme şeklinde olan değerlendirmeler için hakemler, ilgili çalışmaya dair eksik ve kusurlu hususları Hakem Değerlendirme Formu'nda açık ve somut bir şekilde ortaya koymalıdır.

-Hakem değerlendirme raporlarının, DBMD tarafından sağlanan Hakem Değerlendirme Formu'na uygun biçimde ve içerikte hazırlanması ve gönderilmesi gerekmektedir.

-Hakem değerlendirme raporları adil, objektif, özgün ve ölçülü olmalıdır.

-Hakem değerlendirme raporları, ilgili makale ile ilgili yapıcı eleştiriler ve tavsiyeler içermelidir.

Editörlerin Sorumlulukları:

-Editörler, derginin bilimsel kalitesini arttırmak ve yazarları bilimsel kalitesi yüksek araştırmalar üretmek için desteklemek ile sorumludur. Hiçbir koşulda, intihal ya da bilimsel kötüye kullanıma izin verilmemektedir.

-Editörler, dergiye gönderilen her çalışmanın çift-kör hakemlik sürecine ve diğer editoryal süreçlere tabi olmasını sağlamaktadır. DBMD'ne gönderilen her çalışma, çift-kör hakemlik sürecine ve nesnel değerlendirmeye dayalı editör kararına bağlı tutulmaktadır.

-DBMD'ne gönderilen her bir çalışma, uygunlukları açısından editör tarafından değerlendirilir ve daha sonrasında, incelenmesi ve değerlendirilmesi amacıyla en az iki uzman hakeme gönderilir.

-Editörler, yazarlar ile çıkar çatışması olmayan hakemleri, çalışmayı değerlendirmek üzere atamakla sorumludur. Çift-kör hakemlik süreci, editör için değerlendirme ve düzenleme aşamalarında katkı sağlamaktadır.

-Editörler, DBMD'ne gönderilen tüm çalışmaların ön kontrol, tarama, intihal kontrolü, değerlendirme ve düzenleme aşamalarından geçmesini sağlar. Editörler iddia edilen veya kanıtlanmış bilimsel kötü kullanımdan haberdar olurlarsa makaleyi geri çekebilirler. Editörler, gerekli durumlarda gönderilen çalışmayı düzeltme, geri çekme veya çalışma hakkında özür yayınlama hakkına sahiptir.