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Aperture Coupled Microstrip Antenna Design and Analysis using MATLAB

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Abstract **– A linearly-polarized aperture coupled patch antenna design is characterized by using MATLAB software. The aperture coupled patch antenna microstrip feedline, substrates, ground plane slot, and patch dimensions are varied to determine effects on antenna performance which eliminates the electrical connection between the radiating conductors and feed by employing dielectric substrates separated by a ground plane. If exact combination of slot and shape of feed is chosen, it gives an optimum impedance bandwidth with an improved radiation pattern.**

Keywords— Antenna, Matlab, Microstrip patch, substrate

I. INTRODUCTION

Antennas are essential parts in communication systems. An antenna will be outlined as any wire or conductor that carries a pulsing or electrical energy. Such a current will generate an electromagnetic field around the wire and the field will pulse and vary as electric current does. Each antenna is designed for a certain frequency beyond which the antenna rejects the signal. Therefore, it can be deduced that an antenna acts as a band pass filter and a transducer.

The principle objective of a communication system is to transmit information signal from one point to another. The very word Communication refers to sending, receiving and processing the information by external means. The message can originate from any information source irrespective of whether it is speech from an individual or numerical data from a computer. A Communication system always involves a spectrum or band of frequencies and so bandwidths forms an important feature to it. The basic sub-divisions of the Communication system are the source, the transmitter, the transmission path or channel, the receiver and the destination. The source generates the electronic signals to be sent to the receiver. The transmitter represents the part of the system where the information signal or the message signal is modulated over a carrier waveform and then transmitted. The modulation involves varying the parameters of the carrier wave such as amplitude, frequency or phase. The transmission is achieved by using a transducer. Transducer is the name given to the device, which converts one form of energy into another. The transducer converts the physical quantity, in which the information is presented, into a corresponding electrical quantity or vice versa. The transducer at the transmitter is used to generate the electromagnetic wave for the propagation in the transmission path.

The transmitter and the receiver are linked together through the transmission path of circuit which itself associated with distance and is distributed in space. The transmission path represents the propagating media or the electromagnetic path interconnecting the transmitter and the receiver. The receiver performs the necessary operation of receiving the transmitted carrier and recovering the message signal at the desired destination. This transducer converts back the impinging electromagnetic field into electronic signals.

A. ROLE OF ANTENNA

Antennas are the basic components of any electrical system and are the connecting link, which radiate or receive electromagnetic waves between transmitter, free space and receiver. Thus, they play a very important role in finding the characteristics of the system. An Antenna is a system of elevated conductors which couple or match transmitter or receiver to the free space or between free space and guided wave. An antenna is a specialized transducer that converts radio frequency into alternating current and vice versa. At the open end, a phase reversal result causing some of the incident voltage to be radiated away from the transmission line instead of reflected, as in normally the case. The radiated energy is in the form of transverse electromagnetic waves and the amount of radiation emitted can be varied by increasing or decreasing the distance between the conductors.

B. MICROSTRIP PATCH ANTENNA

A microstrip patch antenna (MPA)is a popular resonant antenna for narrow band microwave wireless links that require semi-hemispherical coverage. It consists of a conducting patch of any planar or non-planar geometry on one side of dielectric substrate with a ground plane on other side. The rectangular and circular patches are basic and most commonly used microstrip antennas. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground place. In order to achieve good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable as this provides better efficiency, larger bandwidth and better radiation.

Microstrip patch antennas will be fed by a range of strategies. These strategies will be classified into 2 categories:

- Contacting
- Non-Contacting

RF power is directly fed into the radiating patch using a microstrip line in the Contacting method.

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To transfer power between the microstrip line and the radiating patch, electromagnetic field coupling is done in the non-contacting method.

The four most popular feed techniques used are as follows

- The Microstrip line
- Coaxial probe
- Aperture coupling
- Proximity coupling

TABLE 1
COMPARISON OF DIFFERENT FEED METHODS [1]

Characteristics	Microstrip line	Coaxial Probe	Aperture Coupling	Proximity Coupling
Return Loss	Less	More	Less	More
Spurious Feed Radiation	More	More	Less	Minimum
Ease of Fabrication	Simple	Soldering and Drilling needed	Alignment Required	Alignment Required
Polarization Purity	Poor	Poor	Excellent	Poor
Bandwidth	2-3%	2-3%	21%	13%

C. MATLAB

MATLAB is a high-performance language for technical computing. It integrates programming environment, visualization and computation. Typical uses include

- Math and Computation
- Algorithm Development
- Data acquisition
- Prototyping, modeling, and simulation
- Exploration, Data analysis, and visualization
- Scientific and Engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system which does not require dimensioning for which basic data element is an array which allows solving technical computational problems, especially with vector and matrix formulations.

The MATLAB system consists of five main parts:

- Development Environment
- MATLAB Mathematical Functional Library
- MATLAB Language
- Graphics
- MATLAB Application Program Interface (API)

II. LITERATURE SURVEY

A. Varshney, et al [1] In this paper, the author describes different feeding techniques for wireless microstrip antenna. An antenna excited by different feeding techniques results in differ of gain, efficiency, bandwidth, etc. These feeding techniques gives the flexibility to understand the design parameters of an antenna and their effect of VSWR, Return loss and Resonant Frequency.

B. Raina, et al [3] In this paper, the aperture coupled microstrip antenna is designed operating at 5.75 GHz to 5.85 GHz frequency with both substrates having the same thickness of 1.57mm. On analysis, the obtained VSWR is 1.036 and return loss of -34.827dB. Due to the small size of the antenna, the design can be constructed at a lower cost.

C. Zarreen, et al [4] In this paper, the aperture coupled microstrip antenna coupling mechanism depends on the feed line, patch, and shape of the aperture. By changing the patch shape, impedance bandwidth can be increased. In this design, a thin rectangular shape slot is used. If the shape of slot and feed is tuned perfectly then it gives an improved radiation pattern with optimum impedance bandwidth.

D. Civerolo, et al [5] In this paper, the author presents theoretical and practically identified antenna dimensions and parameters effects and a design procedure which converts performance requirements into operational prototypes. To tune the operating frequency, Slot dimensions and patch were adjusted. On analysis, Bandwidth and Broadside gain depicts improvement on change of design and operating frequency.

E. Tuan-Yung Han, et al [6] In this paper, aperture coupled T-shaped microstrip feed is designed at full wave resonant mode. Additional annular ring slot is to be introduced to reduce the considerable back radiation. At Broadside direction, aperture coupled antenna has low cross polarization. On simulating, the gain is more than 7.5dBi and off-axis cross polarization is of less than -23dB.

III. METHODOLOGY

Microstrip Line Feeding Technique:

In this feeding technique, a conducting strip is directly connected at the edge of the Microstrip patch. When compared to patch, the width of conducting strip is smaller. This type of feed arrangement has an advantage that feed can be etched on the same substrate to provide a planar structure. This is achieved by properly controlling the inset position. As the thickness of the substrate increases, spurious feed radiation, and surface waves increases, and feed radiation leads to undesired cross polarized radiation.

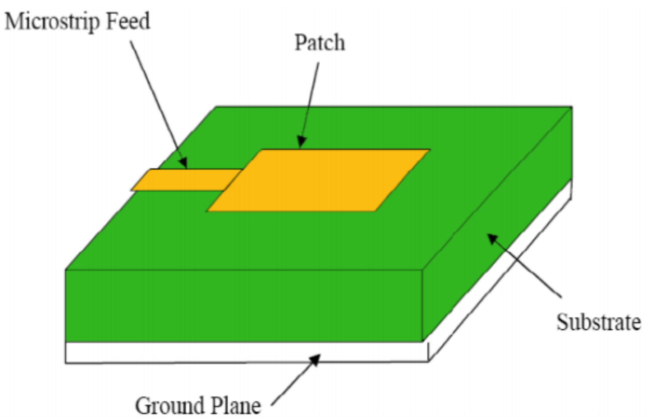

Fig. 1: Microstrip Line Feed [2]

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Aperture Coupled Feeding Technique:

In this type of feeding technique, microstrip feed line and radiating patch are separated by the ground plane. The outer coax conductor is electrically connected to the ground plane. The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to the symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size, and location of the aperture. This feeding scheme also provides a narrow bandwidth. However, the probe center conductor underneath the patch causes undesired distortion in the electric field between the patch and ground plane and produces undesired reactive loading effects at the antenna input port. The undesired reactance can be compensated by adjusting the probe location on the patch.

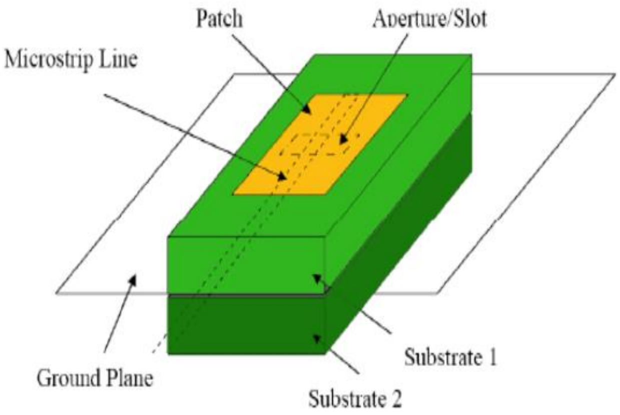
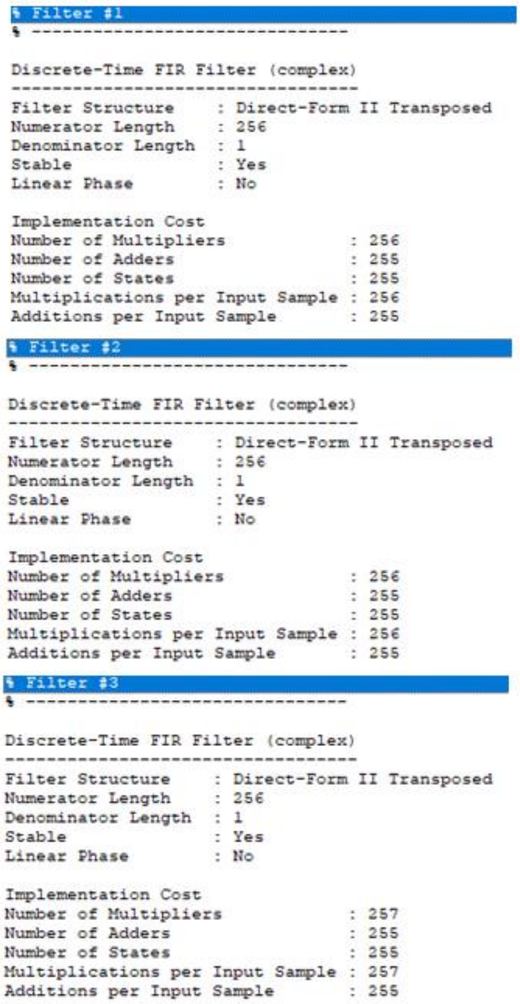


Fig. 2: Aperture Coupled Feed [2]

Rectangular patch is the most commonly employed microstrip antenna which is like a truncated microstrip transmission line which is one-half wavelength long. The resonant length of the antenna is slightly shorter due to the electric fringing fields which increase the electrical length of antenna slightly.

Filter Information:



```
% Filter #1
% --------------------------------

Discrete-Time FIR Filter (complex)
-----------------------------------
Filter Structure    : Direct-Form II Transposed
Numerator Length    : 256
Denominator Length  : 1
Stable              : Yes
Linear Phase        : No

Implementation Cost
Number of Multipliers           : 256
Number of Adders                : 255
Number of States                : 255
Multiplications per Input Sample : 256
Additions per Input Sample      : 255
% Filter #2
% --------------------------------

Discrete-Time FIR Filter (complex)
-----------------------------------
Filter Structure    : Direct-Form II Transposed
Numerator Length    : 256
Denominator Length  : 1
Stable              : Yes
Linear Phase        : No

Implementation Cost
Number of Multipliers           : 256
Number of Adders                : 255
Number of States                : 255
Multiplications per Input Sample : 256
Additions per Input Sample      : 255
% Filter #3
% --------------------------------

Discrete-Time FIR Filter (complex)
-----------------------------------
Filter Structure    : Direct-Form II Transposed
Numerator Length    : 256
Denominator Length  : 1
Stable              : Yes
Linear Phase        : No

Implementation Cost
Number of Multipliers           : 257
Number of Adders                : 255
Number of States                : 255
Multiplications per Input Sample : 257
Additions per Input Sample      : 255
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Fig. 3: Filter Information

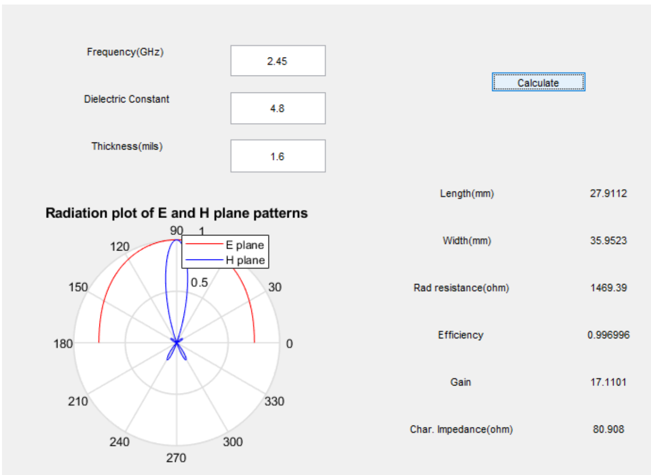

Fig. 4: Radiation plot at 2.45 GHz

The Radiation plot has been designed by considering 2.45 GHz as operating frequency with FFR-4(lossy) substrate of dielectric constant 4.7 and thickness of the patch as 1.6 mm. On considering these parameters efficiency is 99.6% and Characteristic Impedance of 80.908 ohms.

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IV. RESULTS

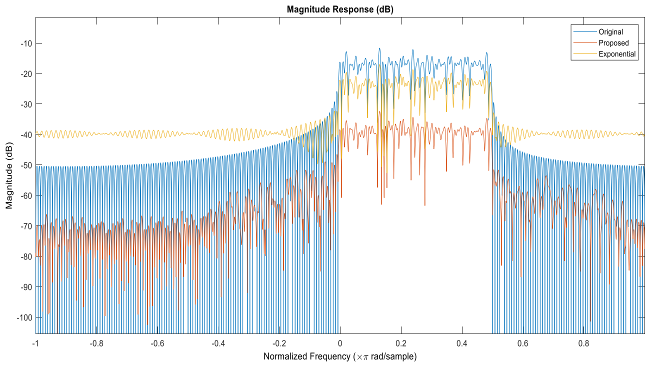

Fig. 5: Magnitude Response

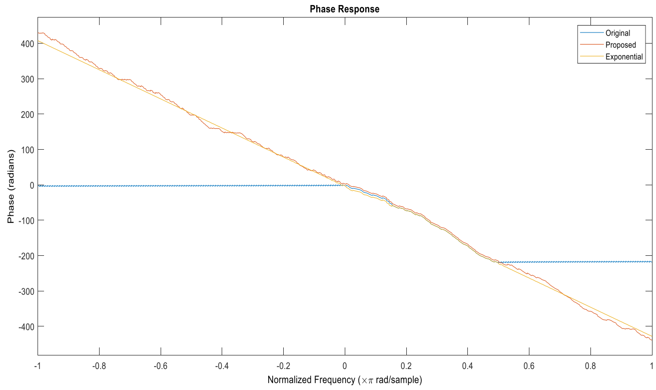

Fig. 6: Phase Response

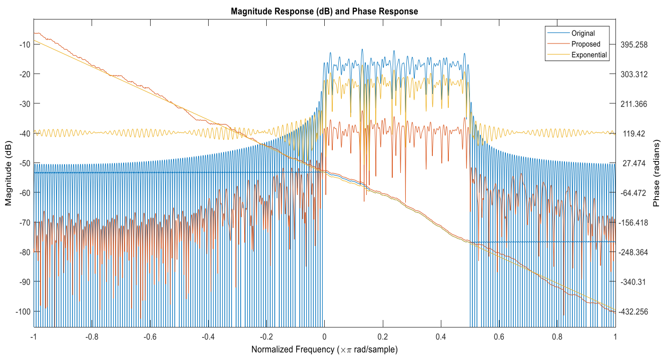

Fig. 7: Magnitude and Phase Response

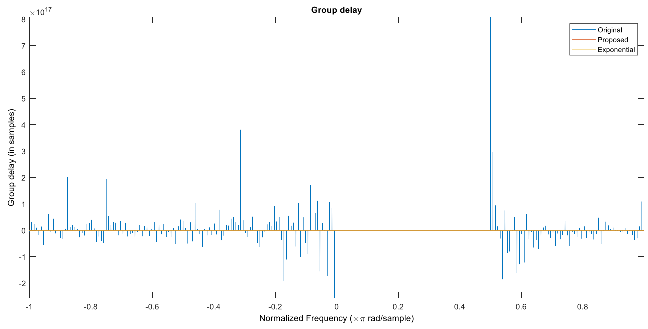

Fig. 8: Group Delay

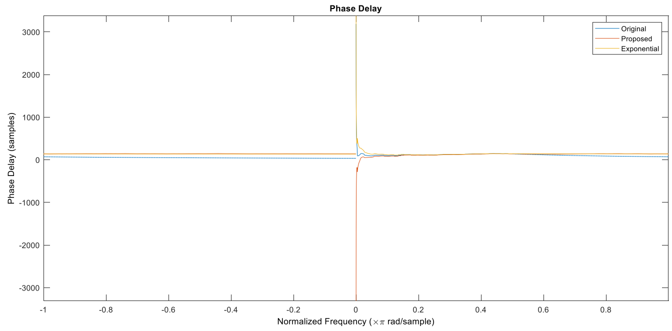

Fig. 9: Phase Delay

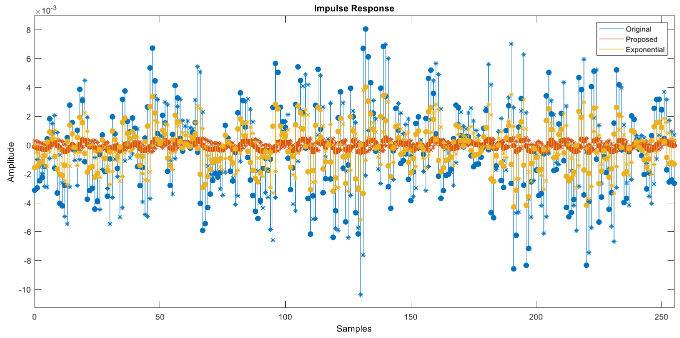

Fig. 10: Impulse Response

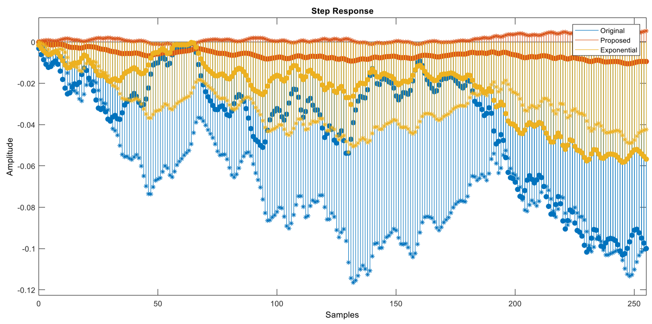

Fig. 11: Step Response

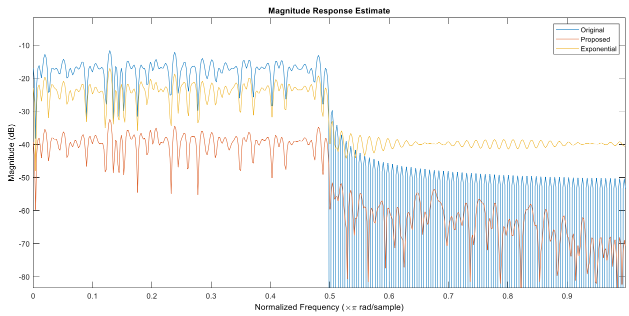

Fig. 12: Magnitude Response Estimate

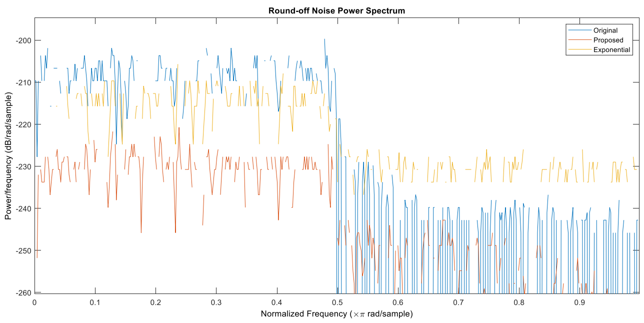

Fig. 13: Round-off Noise Power Spectrum

V. ADVANTAGES

i. Eliminates spurious radiation.
ii. Feed-line radiation is isolated from patch radiation.
iii. Allows for planar feeding.
iv. Higher bandwidth is possible since probe inductance is eliminated, and double resonance can be created.

VI. CONCLUSION

An aperture coupled microstrip patch antenna has been designed according to design specifications, simulated and analyzed. The proposed design has simple structure and it can be constructed with a lower cost.

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