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MICROSTRIP PATCH ANTENNA DESIGN FOR 5G APPLICATIONS

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Abstract:
The evolution of communication systems toward the fifth generation (5G) requires high-speed and compact systems that can work on wide-bandwidth. In this research, we are focusing on designing and simulating a microstrip patch antenna that is operating at 24 GHz. The dimensions of the antenna are 9 mm × 8 mm × 0.254 mm, ensuring a compact structure. It resonates at 24.13 GHz, having a return loss value of -49.747 dB, offering a gain of 7.59 dBi, a bandwidth of 600 MHz, and directivity of 8.476 dBi. The design utilizes a Roger RT 5880 substrate. Antenna geometry is thoroughly calculated, and simulation results are analyzed using Computer Simulation Technology Studio.

Keywords:
Microstrip, Patch Antenna, 5G, Bluetooth, Communication, Frequency

1. INTRODUCTION:

Microstrip antennas find applications in various fields due to their versatility and compact design. It is a type of antenna that operates in the microwave frequency range. Some common areas in which microstrip antennas are used include Wireless Communication Systems, Satellite Communication, Radar Systems, RFID and also in automotive systems. In wireless communication system, they are used in mobile phones, Wi-Fi routers, WiMAX technology, and also in Bluetooth devices. Microstrip antennas have a crucial role in 5G technology, they contribute to the development of compact, high-performance communication systems. Microstrip antennas are suitable for millimetre-wave communication due to their small size and ability to achieve directional radiation patterns, which are essential for mitigating propagation losses and interference.

2. ANTENNA DESIGN:

The designing of an antenna includes various steps like geometry optimization, simulation and analysis of it's performance. Using standard microstrip patch design techniques, the patch antenna is designed to resonate at 24.13 GHz frequency. The dimensions of the antenna are determined on the basis of desired resonance frequency and other performance parameters. Subsequently, changes in the antenna geometry are done by making cuts in the antenna design. The dimensions of the cuts are optimised to achieve the desired resonance frequency. The Figure 1 displays the design of the Microstrip Patch Antenna that is being proposed. The proposed antenna dimensions are as follows:

S. No.	Parameters	Value
1.	Length of Ground	9 mm
2.	Width of Ground	8 mm
3.	Height of Ground	0.025 mm
4.	Length of Substrate	9 mm
5.	Width of Substrate	8 mm
6.	Height of Substrate	0.254 mm
7.	Length of Patch	5.70 mm
8.	Width of Patch	3.95 mm
9.	Length of Feed Line	4.70 mm
10.	Width of Feed Line	0.89 mm

11.	C1	0.80 mm
12.	C2	0.88 mm
13.	C3	1.13 mm
14.	C4	1.80 mm

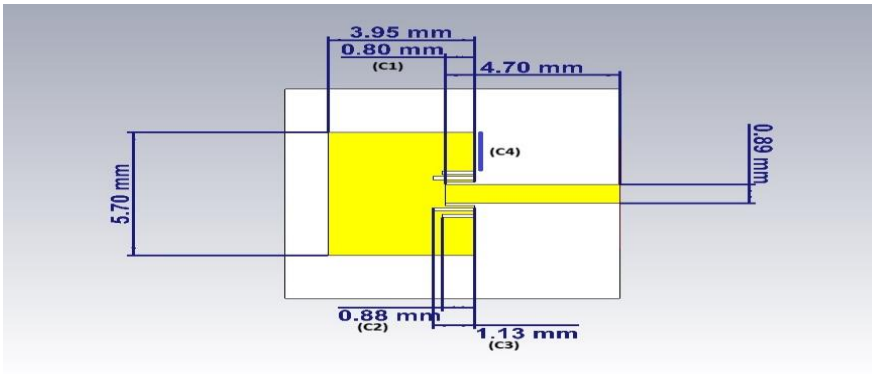

Figure 1: Proposed Microstrip Patch Antenna Design

The Figure 2 shows an example of conventional design of a Microstrip Patch without cuts.

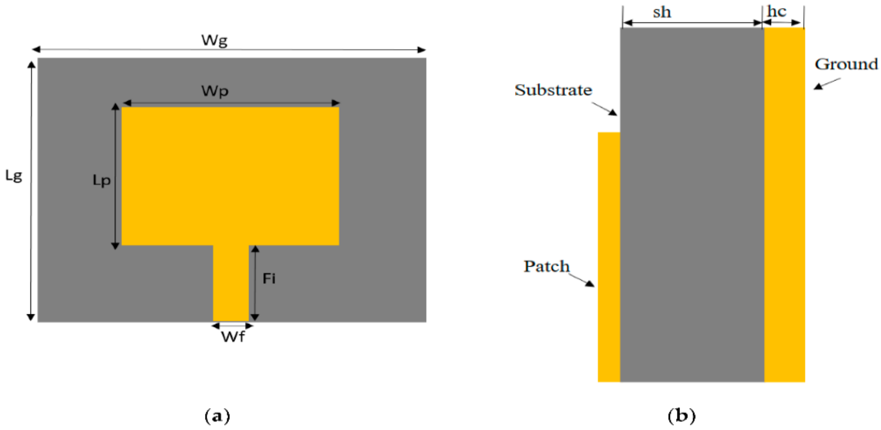

Figure 2: Conventional Microstrip Patch Antenna Design

The Figure 3 demonstrates the S-parameter of a traditional Microstrip patch antenna without cuts.

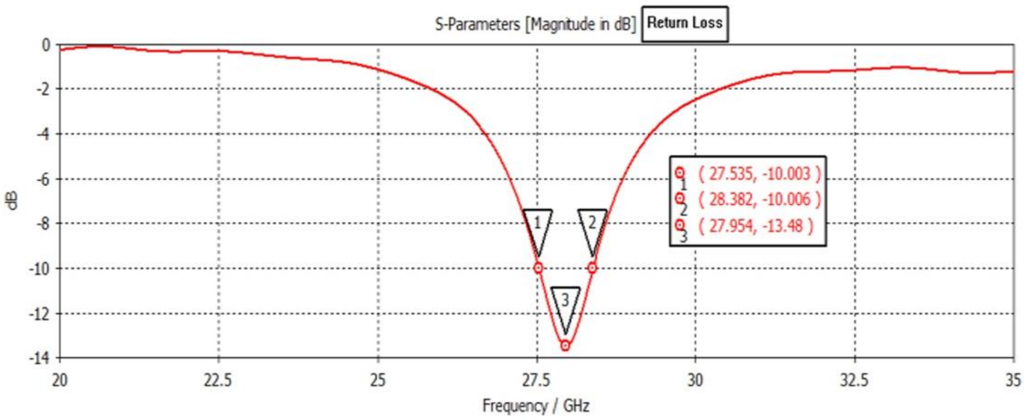

Figure 3: S-Parameter of a Conventional Microstrip Patch Antenna

3. Designing of Microstrip Patch Antenna with modifications:

The Microstrip Patch antennas are used in wireless communication systems due to their unique advantages like they can be modified according to our need of dimensions and performance also. When we introduce specific design modifications like a cut in the antenna design, we are able to have an influence on antenna's performance and further use it for various kinds of applications.

Improving the performance:
The introduction of cuts in the antenna design can help to widen it's bandwidth. It can also help us in impedance matching of the antenna.

Radiation Pattern Improvement:
The Radiation Pattern of the antenna can also be improved by designing the dimensions and shape of the cuts. This improvement can further help in improving directivity, gain and other coverage characteristics. This can be helpful if there are specific-application requirements.

Adjustment of Frequency Band:
Fine tuning of the Frequency band can be achieved by having a cut in the patch. When we place the cut calculatedly, we can adjust the projected direction of frequency on the upper as well as the lower side. This increases its versatility and flexibility in communication systems.

4. Simulation Results:

CST (Computer Simulation Technology) can be used to simulate a microstrip patch antenna. By doing so, we can obtain various valuable results like Gain, Directivity, Return Loss, VSWR (Voltage Standing Wave Ratio), Bandwidth and other performance parameters as well.
Simulating the proposed antenna on CST provides following results:

A) RETURN LOSS:
In an antenna, Return Loss is the measurement of power that is being reflected back towards the source because of a mismatch in the impedance between the transmission line or the surrounding environment and the antenna. Return Loss is expressed in decibels (dB). If the return loss value is high, it indicates superior impedance matching, and hence it shows that less power is being reflected back to the source, which is desirable for efficient signal transmission.
In simpler terms, return loss represents the amount of signal that "bounces back" towards the transmitter rather than being radiated outward by the antenna. It's an important parameter in antenna design and performance evaluation, as it directly affects the efficiency and effectiveness of signal transmission.

Figure 4 shows us the Return Loss by the proposed design of antenna. Return Loss of -49.747 indicates good impedance matching.

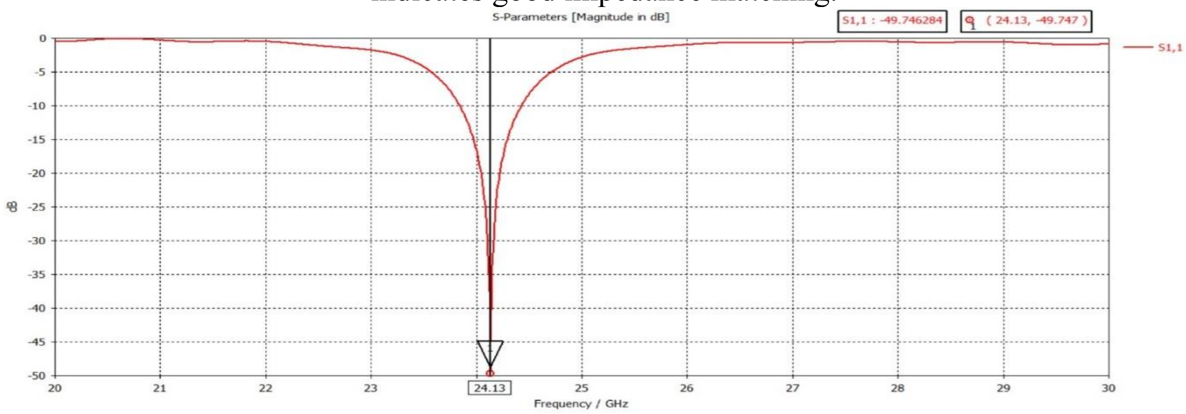

Figure 4: Return Loss of the Proposed Microstrip Patch Antenna

B) BANDWIDTH:
The antenna bandwidth is the range of frequencies in which the antenna operates efficiently. It can also be defined as that range of frequency where the performance of the antenna meets certain desired criteria, such as a specified level of return loss, gain, or efficiency.
In simpler terms, bandwidth represents the range of frequencies over which an antenna can receive or transmit signals effectively without significant degradation in performance. Wider bandwidth allows the antenna to operate over a greater frequency range, hence making it more diverse and suitable for versatile communication applications.

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From Figure 5, we can infer that the Bandwidth of the microstrip antenna being proposed is 600 MHz.

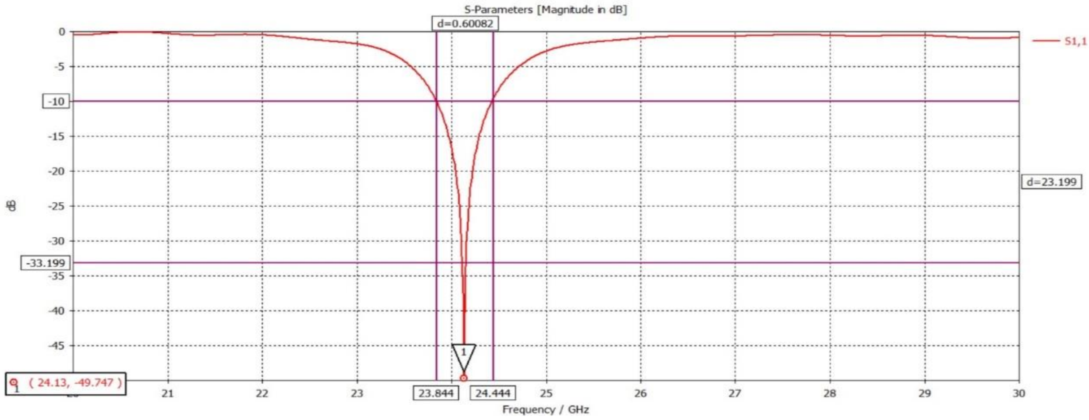

Figure 5: Bandwidth of Proposed Microstrip Patch Antenna

C) GAIN:

The gain of an antenna tells us how well it focuses radio waves in a particular direction when we are sending them out or how well it picks up signals from a specific direction when we are trying to receive them.

Higher gain values indicate that the antenna is more effective at transmitting or receiving signals in the desired direction. However, it's important to note that gain is always relative to a reference, such as an isotropic radiator or a dipole antenna, and does not imply amplification of signal power.

From Figure 6, we can observe that the Gain of the microstrip antenna being proposed is 7.5992 dBi, that is, decibels relative to an isotropic radiator.

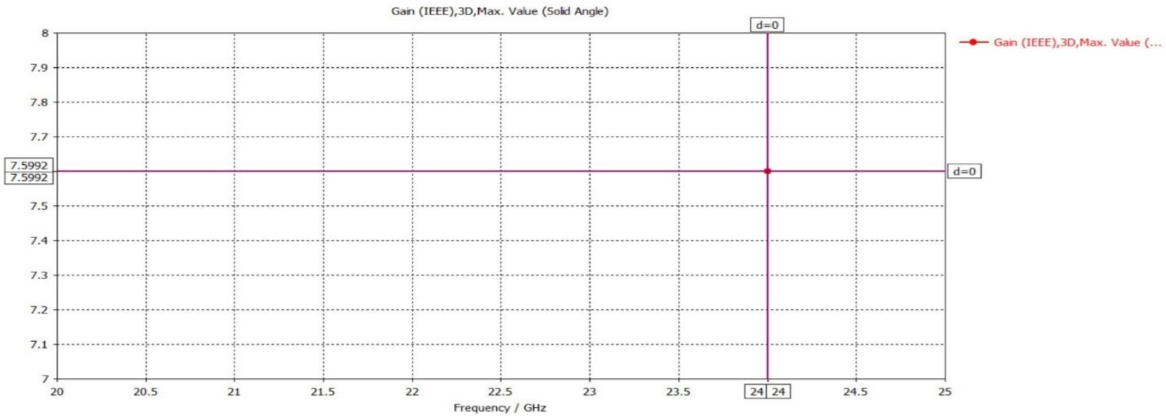

Figure 6: Gain of the Microstrip Antenna being proposed

D) DIRECTIVITY:

Directivity in an antenna refers to its ability to concentrate or focus radio frequency (RF) energy in a specific direction when transmitting, and also to receive signals more effectively from a distinct direction when receiving.

In simpler terms, directivity indicates how "directional" an antenna is. Antennas with high directivity concentrate their energy into a narrower beam, allowing for longer-range communication in a specific direction.

From Figure 7, we can infer that the Directivity of the proposed Microstrip Patch Antenna is 8.476 dBi, that is, decibels relative to an isotropic radiator.

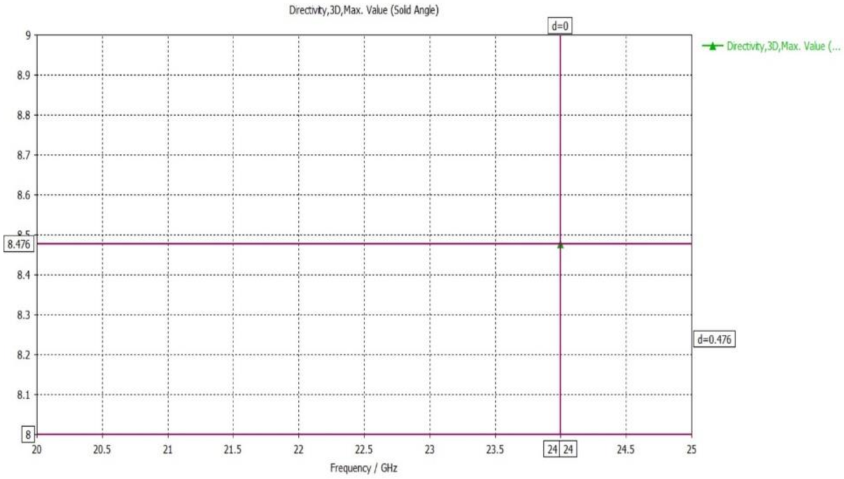

Figure 7: Directivity of the Microstrip Patch Antenna being proposed

E) EFFICIENCY:

An antenna converts the power being input into electromagnetic energy to be radiated. Efficiency refers to how well the antenna converting the input power. It is a measure of the antenna's effectiveness in transmitting or receiving signals without dissipating power as heat or losses in the system.

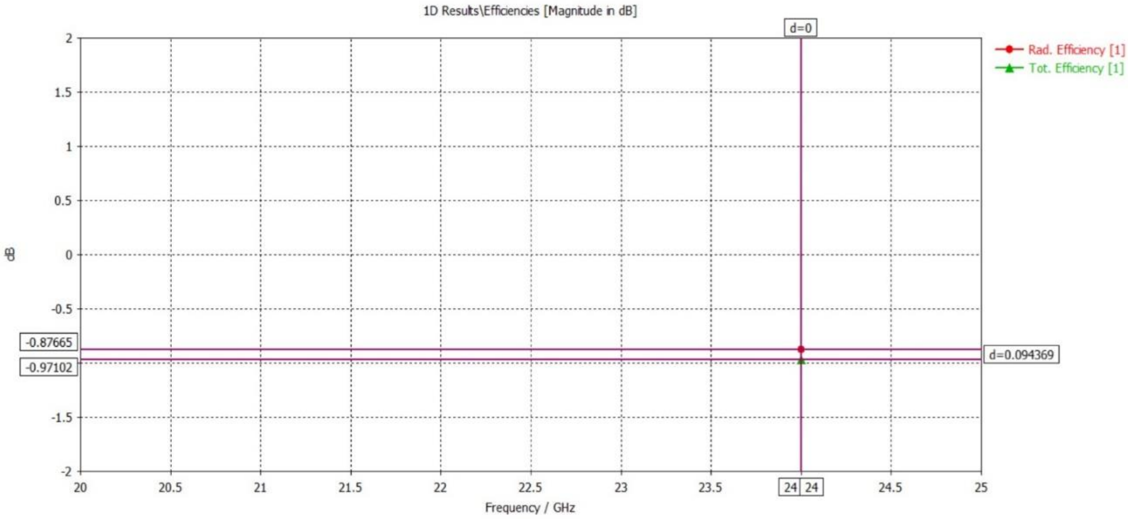

Figure 8: Efficiency Graph of the Proposed Microstrip Antenna

F) VSWR:

VSWR stands for Voltage Standing Wave Ratio. It is a representation of how good an antenna is matched to the transmission line or the connected system. When the antenna impedance doesn't match the transmission line impedance or that of the connected system, some of the energy sent down the line gets reflected back.

VSWR quantifies how much of the original signal is reflected back due to this mismatch. A VSWR value of 1 means all the energy sent down the line is getting through without any reflection, which is the ideal scenario. As the VSWR value increases, it indicates more energy is being reflected back, meaning poorer matching between the antenna and the system.

In practical terms, lower VSWR values are desirable because they indicate better impedance matching, which leads to more efficient signal transmission and reception. VSWR is a very important parameter in designing of an antenna and evaluation of its performance.

Figure 9 shows us the VSWR offered by the proposed Microstrip Antenna. A value of 1.006 shows us that the proposed microstrip patch antenna is performing quite good.

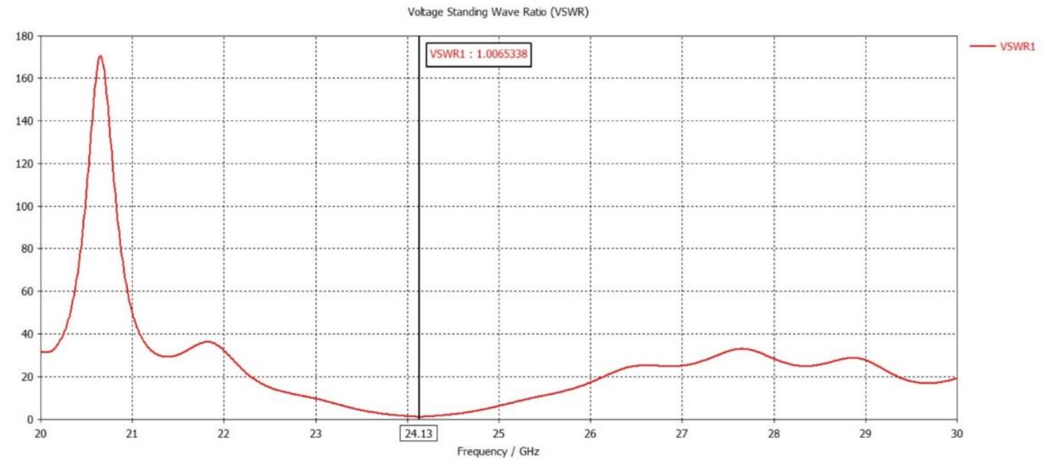

Figure 9: VSWR offered by the proposed Microstrip Patch Antenna

G) RADIATION PATTERNS:

The radiation pattern of an antenna describes the distribution of electromagnetic energy it emits or receives in three-dimensional space. It illustrates how the antenna radiates or receives energy in different directions.

Understanding the radiation pattern of an antenna is very important for designing and optimizing wireless communication systems, as it directly affects how effectively signals can be transmitted or received in different directions.

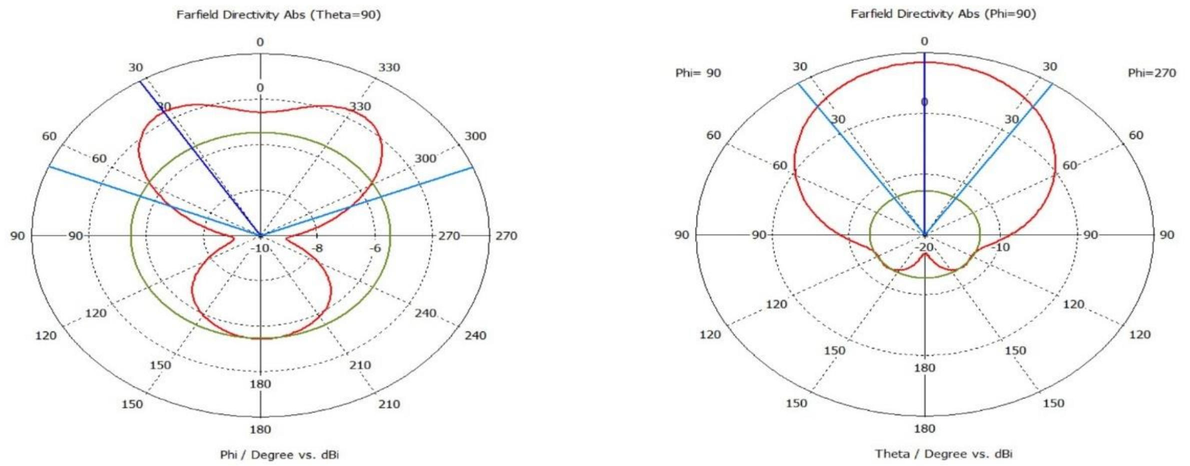

Figure 10: Radiation Pattern of the Proposed Microstrip Patch Antenna

5. Conclusion:

In this research, we are proposing a Microstrip Patch Antenna design to get our desired performance results. The antenna is designed in such a way that it can be used in 5G Applications as it resonates at the frequency 24.13 GHz, which comes under the 5G mmWave specification.

Through computer simulation technology and theoretical analysis, we can infer that the proposed antenna is performing exceptionally good in important performance parameters of an antenna like Bandwidth, Directivity, Gain and VSWR.

6. Applications and Uses:

i) **Cellular Networks:**

5G mmWave technology works in the frequency range of 24GHz and above. The proposed antenna can resonate at the frequency 24.13 GHz; hence it can operate at the desired frequency range.

ii) **Possible future application in 6G Technology:**

After 5G technology, the next wireless communication technology being developed is the 6G (Sixth generation) technology, it is currently in the development stage, but as per the initial phase of research, the operating frequency range of 6G will be similar to that of the existing 5G technology, so the antenna that is being proposed may also be used for 6G applications in the future.

iii)**Radio Telescope:**

It is an astronomical device that comprises of an antenna system that is used to detect radio frequency range between 30 MHz to 300 GHz.

iv)**Radar Networks:**

The K band radar waves fall between 18 to 27 GHz, making the antenna useful for radar applications in surveillance, aerospace as well as defence.

7. Acknowledgement:

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