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Compact Single Band Suppression Monopole Antenna for SWB Application

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ABSTRACT

This article describes the design of a miniatured monopole antenna with a band notch for use in super-wideband applications. The suggested antenna is fed by a triangular tapered micro-strip feed line and has a frequency range of 2.88 to 60 GHz (bandwidth ratio: 20.83:1) with |S11|<−10 dB, with the exception of the notched band for WLAN band at 4.35–6.45 GHz. The antenna's overall dimensions are 23 × 14.5 × 1 mm^3 which consists of F4B substrate having permittivity of 2.65 and 1mm thickness, a round-cornered beveled-shaped radiating element, and a round-cornered partial ground plane. To realize the band notch characteristic an inverted crescent shape slot is introduced in the radiator. This paper presents the simulated results for the suggested antenna. The results shows that the suggested antenna operates well over the whole operational BW (181.7%), making it a good choice for SWB applications.

Keywords - **Super wideband; Band-notch function, Tapered microstrip feed line, Miniature Size, Crescent Shape,**

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I. INTRODUCTION

Printed monopole antennas are in high demand in the modern epoch of wireless technology due to the many desirable characteristics they possess. This includes being able to support wideband transmissions, being small, having a high-speed data connection, and being able to send signals in all directions. Presently the printed monopole antennas are being considered for super wide-band applications due to all of these features. Antennas with a decade bandwidth (10:1) that can support to minimal levels are known as SWB antennas. As a result of its wider bandwidth and higher data rate, SWB technology is able to send information such as voice calls, videos, and data at a faster speed than is feasible with other technologies. In comparison to an ultra-wideband (UWB) antenna (3.1 to 10.6 GHz with an effective bandwidth ratio of 3.4:1), the SWB antenna offers an extraordinarily large bandwidth, inspiring the researchers to further examine the SWB antenna. As a result, the design of super wide-band compact antennas while maintaining wideband characteristics is a difficult task in the field of modern wireless systems. So, right now, a lot of researchers are working to achieve a trade-off between increasing the bandwidth and making the antennas smaller. Many researchers have made significant contributions to the design of SWB and UWB antennas over the past few years. A number of super wideband and ultra-wideband antennas having either no notch, single notched band, or multiple notched band features have been reported in the literature. An enhanced bowtie antenna fed with a micro-strip feed line is examined in [1]. This antenna has a fractional bandwidth of 13:1 (420 MHz–5.5 GHz) and physical dimensions of 230 mm x 230 mm. In [2], triple-notched band ultra-wideband (UWB) antenna in the shape of a maple leaf with a partial ground plane was investigated. Its impedance bandwidth ranged from 1.4–11.3 GHz. In [3], a monopole antenna for wideband applications (from 3 to 50 GHz) with a defective ground plane that is fed via a triangle tapered feedline. This antenna can be used for both C and X-band applications. A monopole antenna with an octagonal ring shape is reported in [4], which covers a frequency band from 2.59 to 31.14 GHz. The impedance bandwidth was improved by inserting a stub in the main patch. This enabled the antenna to cover a wider frequency range. A coplanar waveguide fed SWB antenna with triple notched characteristics is reported in [5]. The notch features were created with two elliptical slots and an inverted T-shaped stub. By merging four ellipses with an eccentricity ratio of 0.5, it was possible to achieve the compactness of the antenna. In [6], a compact circular-shaped antenna that has dual notched band features with an operational frequency from 1.60 to 25 GHz is discussed. An octagonal Sierpinski band-notched SWB antenna with defective ground is discussed in [7]. In [8], a SWB monopole antenna is presented. It has a tri-band notch feature, although all of the rejection bands correspond to the UWB range. Furthermore, the antenna is unable to sustain the lower frequency range. A star-shaped antenna with a rejection band is given in [9] for high-speed WLAN applications. A stop band filter with a split ring resonator (SRR) base is placed in the ground plane to provide a rejection band characteristic, which reduces the interference effect from wireless local area networks. The SWB antenna features are found in only a few articles because it is extremely difficult to achieve an exceptionally large bandwidth with a consistent radiation pattern at higher frequencies [10-16]. In the past few years, several SWB antennas have been made to cover lower frequency applications while still being able to work across a wide range of frequencies [17–19]. Although the presented studies covered the majority of the lower frequency band, the band notch features were not ensured. A monopole antenna with a BW ratio of 13:1 is presented in [20]. This antenna does, however, have certain concerns with its radiation characteristics. In [21], a novel SWB antenna with a triangular tapering feedline and a semicircular ground plane is proposed. The suggested antenna has a peak gain of 7.67 dB and works from 1.42 GHz to 50 GHz. For use in military applications, a microstrip patch antenna has been presented in [22]. A gain of 4.2 dB and a directivity of 4.1 dB are displayed by the suggested antenna. In addition, several SWB antennas are discussed in [23-28].

In this study, we suggest a compact antenna configuration that can provide SWB radiation properties and notch functionality. Here, we show how a broader impedance bandwidth may be obtained by using a tapered feed line for the radiating element. The suggested SWB antenna can provide a wide impedance bandwidth (2.88–60 GHz) by rounding both corners of the partial ground and the radiating part. In comparison to existing SWB antennas, the proposed SWB antenna may meet all essential requirements in terms of SWB radiation characteristics, bandwidth, and size reduction. Furthermore, we introduce a suitable notch at this frequency so as not to interfere with the 5 to 6 GHz range used in WLAN. In the radiating patch, we used an inverted crescent-shaped slot. For a variety of contemporary communication applications, the proposed antenna shows great promise.

II. THE DESIGN OF THE SWAB ANTENNA

Figure 1(a–d) explains the design approach for the SWB antenna. Figure 1(a) displays a monopole antenna that has been developed with a rectangular shaped radiator, a rectangular micro-strip feed line, and a partial ground plane. Figure 2 shows that the rectangular-shaped monopole antenna mismatched at lower frequencies. Since the length of the current path tells how well a wideband monopole antenna works in terms of bandwidth, so the rectangular radiator was changed to a bevel shape with a round-cornered as illustrated in figure 1(b), and the ground plane was also changed to a round-cornered finite ground plane as illustrated in figure 1(c). Both of these modifications were made in order to improve the antennas' ability to follow the longest current path. Modifying the radiator and ground had a positive impact on bandwidth, as seen in figure 2. Finally, to get optimal matching the rectangular microstrip feed line was altered to a triangular tapered line. Figure 1d shows that the width of the rectangular tapered feed line decreased linearly as it got closer to the radiating element. This allowed the maximum range of resonance frequencies to be covered. In the suggested design, the substrate was F4B, and it had a dielectric constant of 2.65 and a thickness of 1 mm. Computer simulation technology (CST) is used for the simulations. The results of simulation revealed that the maximum matching is achieved from 2.88GHz up to 60GHz. In order to create a band notch characteristic an inverted crescent shape slot is introduced in the radiating element. The final schematic of the suggested antenna with a notch characteristic is given in figure 3 while table I provides the optimum dimensions for the designed antenna.

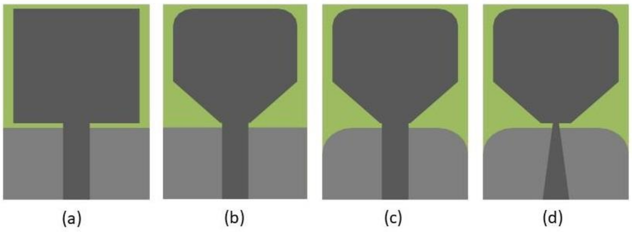

Fig. 1. Design steps of the Suggested Antenna

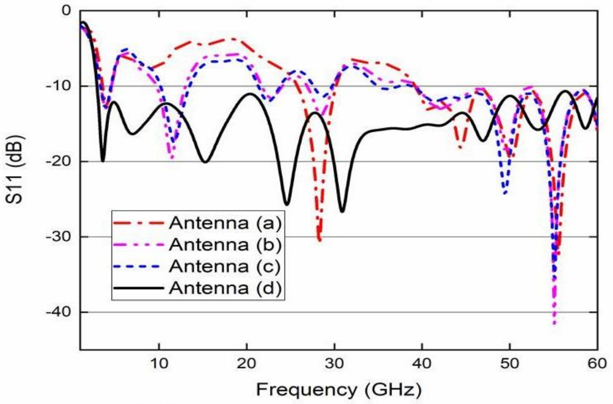

Fig. 2. S11 Comparison for each step of the suggested design

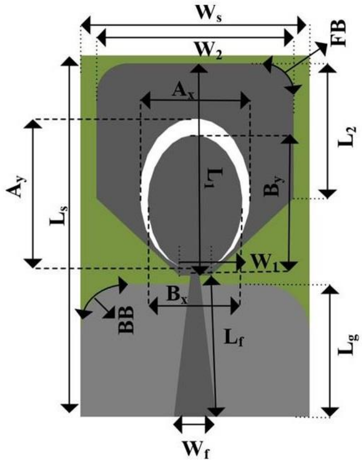

Fig. 3. Designed Antenna Schematic Diagram

III. PARAMETRIC STUDY

The suggested antenna is analyzed in terms of how ground plane length and an inverted crescent-shaped slot affect its performance. To get the right impedance matching, the distance between the ground plane and the component that radiates is important. Figure 4 shows how the suggested SWB antenna simulated reflection coefficient changes when the ground plane length (Lg) is modified. The length Lg is changed between 6.45 and 8.45 mm, but the other dimensions of the antenna stay the same. Impedance matching degrades in the higher frequency bands as ground length Lg is shortened or lengthened. When Lg is extended to 8.45 mm, the antenna resonates in the super-wideband (SWB) frequency range. As presented in figure 5, a parametric analysis of the major axis, minor axis and position of the crescent slot is carried out, in order to better investigate the behavior of the notch band. The variations in the reflection coefficients that occur as a result of changing the crescent slot major axis and minor axis (A_x, A_y) are illustrated in Figure 5a. It has been observed that as the value of major and minor axis are raised, the notch band shifts to lower frequencies. On the other hand, when the major and minor axis of the crescent slot is reduced, the notch band moves to the higher frequencies. Figure 5b illustrates the differences in the reflection coefficients at the crescent slot location. The center frequency of the notch-band is shown to moved to lower frequency range when the value decline from (1 to -1.2 mm). The notch band also moves to the lower frequency range. The design parameters for the suggested antenna are optimized based on the size of the patch and the frequencies needed for the notch band.

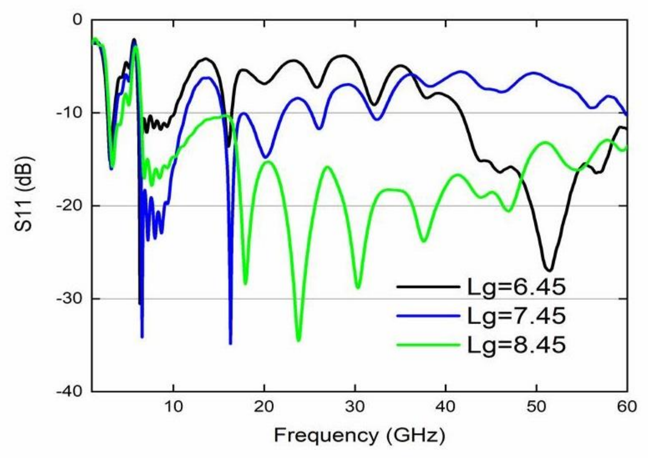

Fig. 4. S-parameter for different values of (Lg)

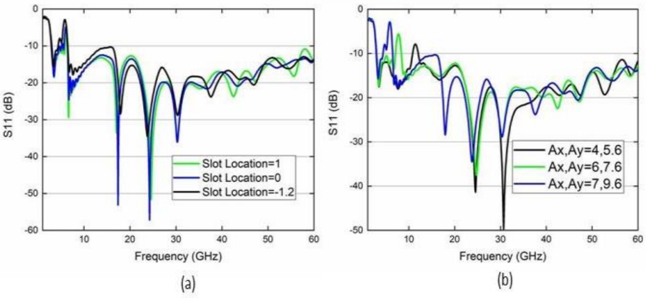

Fig. 5. In (a) S-parameter for different values of Slot location and (b) S-parameter for different values of Ax and Ay

IV. RESULTS AND DISCUSSION

Figure 6 displays the simulated VSWR curves with and without notch. It can be seen that by introducing an inverted crescent shape slot in the radiator a strong rejection at the band-notched region is absorbed. As shown in figure 3, the suggested antenna was designed and simulated. Corresponding to frequency of 5.8 GHz, the rejection of the simulated peak VSWR is 6. Figure 7 depicts two curves: one represents the simulated gain without notch, while the other represents the simulated gain with notch. At higher frequencies, the simulated gain increases linearly as a result of a wavelength that is longer than the corresponding frequency at higher frequencies. The band-notch antenna has a sharp decline in gain from 4.35 to 6.45 GHz, indicating that its performance is reduced in rejecting bands while still performing satisfactorily at other frequencies.

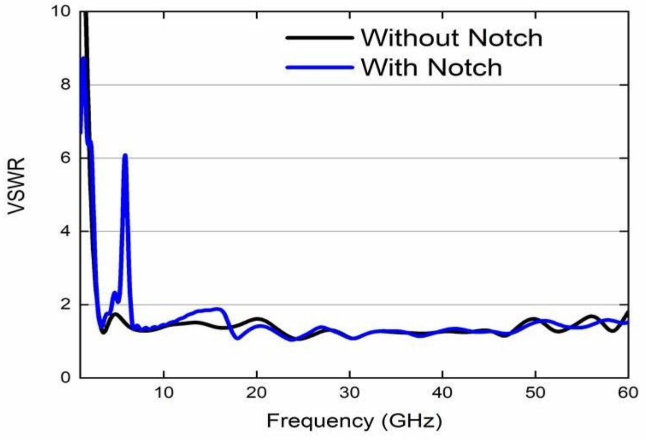

Fig. 6. VSWR With and Without Notch

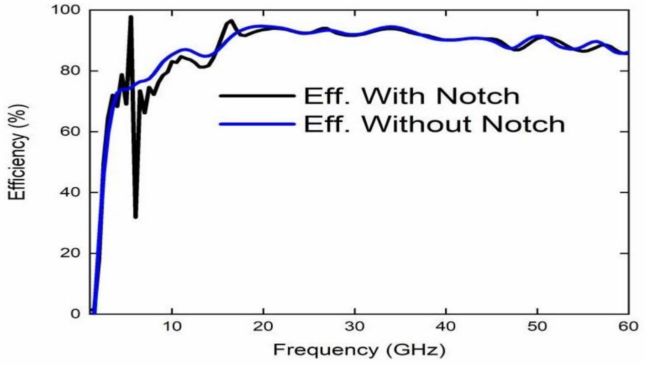

Fig. 7. Gain with and without Notch

In figure 8, the suggested antenna's radiation and total efficiency are displayed. The figure displays the highest radiation efficiency of the suggested antenna which is roughly 96.55%.

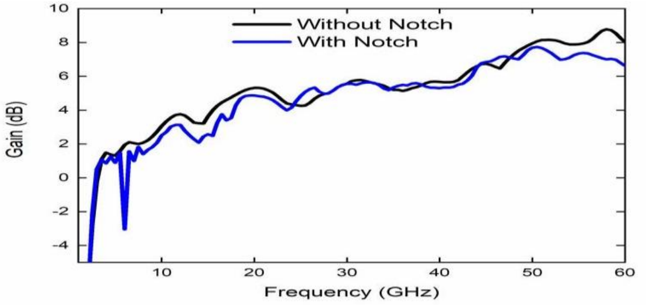

Fig. 8. Suggested antenna efficiency with and without notch

Figure 9 (a-d) depicts co-polarization as well as cross-polarization in the E-plane and the H-plane for the frequencies of 10, 20, 30, and 40 GHz, respectively. At lower frequencies the cross polarization is less, but it increases as the frequency increases. Figure 9 show that the proposed antenna has almost omnidirectional radiation properties. Cross polarization is seen to increase a little bit at higher frequencies because hybrid modes are excited at those frequencies.

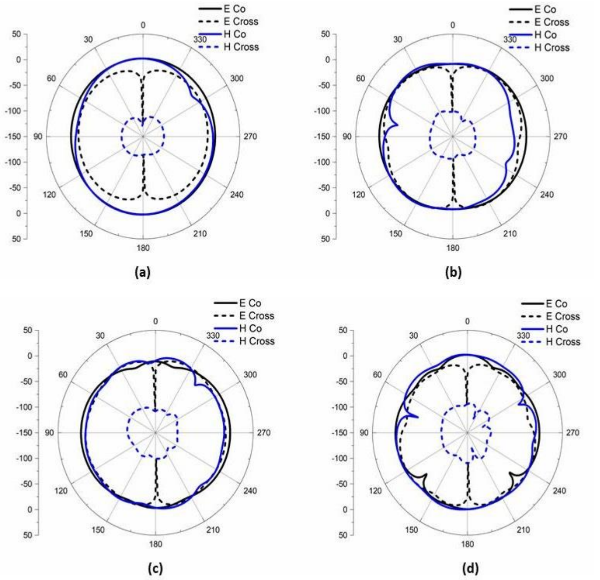

Fig. 9. Radiation Pattern E Co, E Cross and H Co, H Cross at 10, 20, 30 and 40 GHz

The suggested antenna is compared to numerous current designs and is given (Table II).

The surface current distribution for the suggested antenna is revealed in figure 10 at the band notched center frequency of 5.4 GHz. The current is mainly absorbed at the edge of the inverted crescent shape slot. At the intended stop band frequency, the current flows in the opposite direction near the corner of an inverted crescent-shaped slot. This shows that the most energy is lost at that frequency.

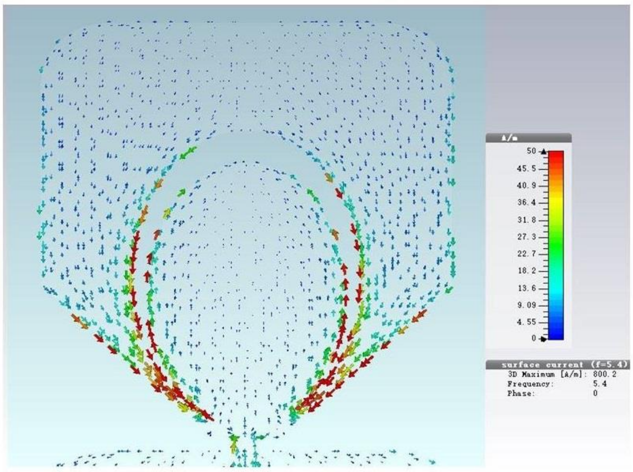

Fig. 10. Surface Current distribution at band-notch center frequency 5.4 GHz

TABLE I. DIMENSIONDS OF DESIGNED ANTENNA

Parameters	Values (mm)	Parameters	Values (mm)	Parameters	Values (mm)
W_s	14.5	W_t	0.6	W_1	2
L_s	23	$L_{f=}$	9	W_f	2.65
L_1	13.5	L_g	8.45	W_2	12.5
FB	2	L_2	8.6	BB	3
a	2	h	1	b	0.5
A_x	7	A_y	9.6	B_x	6
B_y	8.6				

TABLE I I. COMPARISON WITH EXISISTING DESIGNS

Reference No.	Dimensions (mm^2)	BW:1	Fractional Bandwidth	Frequency: range (GHz)	Notched function	Peak Gain (dB)
[1]	$0.32\lambda \times 0.32\lambda$	13:1	171.42%	0.42 - 5.5	-	7.96
[2]	$0.154\lambda \times 0.159\lambda$	-	-	1.4 - 11.3	Yes	4.6
[3]	$0.30\lambda \times 0.30\lambda$	16.66:1	177%	3 - 50	Yes	10
[4]	$0.34\lambda \times 0.34\lambda$	12.02:1	169%	2.59 - 31.14	-	5
[5]	$0.25\lambda \times 0.29\lambda$	14.32:1	174%	2.76 - 39.53	Yes	6.88
[6]	$0.12\lambda \times 0.16\lambda$	15.63:1	176%	1.6 - 25	Yes	6
[7]	$0.23\lambda \times 0.30\lambda$	-	158.28%	3.68 - 31.61	Yes	9.75
[8]	$0.26\lambda \times 0.30\lambda$	20.4:1	159.4%	2.6 - 23	Yes	7.8
[9]	$0.32\lambda \times 0.45\lambda$	-	120%	3.25 - 13	Yes	6.7
[12]	$0.45\lambda \times 0.45\lambda$	19.4:1	180.4%	1.0 - 19.4	-	-
[13]	$0.47\lambda \times 0.32\lambda$	11.8:1	168.66%	1.7 - 20	-	7.24
[14]	$0.32\lambda \times 0.34\lambda$	11:1	166.66%	3.4–37.4	-	11
[15]	$0.17\lambda \times 0.37\lambda$	13:1	172%	1.4 - 18.8	-	7
[16]	$0.20\lambda \times 0.35\lambda$	11.6:1	168.4%	3 - 35	-	11.2
[17]	$0.16\lambda \times 0.13\lambda$	14.56:1	174.29%.	0.96 - 13.98	-	5.8
[18]	$0.17\lambda \times 0.13\lambda$	11.35:1	167.22 %	0.96 - 10.9	-	-
[19]	$0.11\lambda \times 0.075\lambda$	24.8:1	184.5%	0.9 - 22.35	-	4.25
[20]	$0.17\lambda \times 0.37\lambda$	13.06:1	172%	1.44 - 18.8	-	7
[Our Work]	$0.139\lambda \times 0.220\lambda$	20.83:1	181.7%	2.88 - 60	Yes	7.74

In addition, the matching performance of the designed SWB antenna is presented in the form of input impedances in Figures 11a–c. As shown in Figures 11a and 11b, the real and imaginary parts of the simulated input impedance were about 50 ohms and 0 ohms, respectively, across the range of operating frequencies. The magnitude of the impedance would have been around 50 ohms, as seen in Figure 11c.

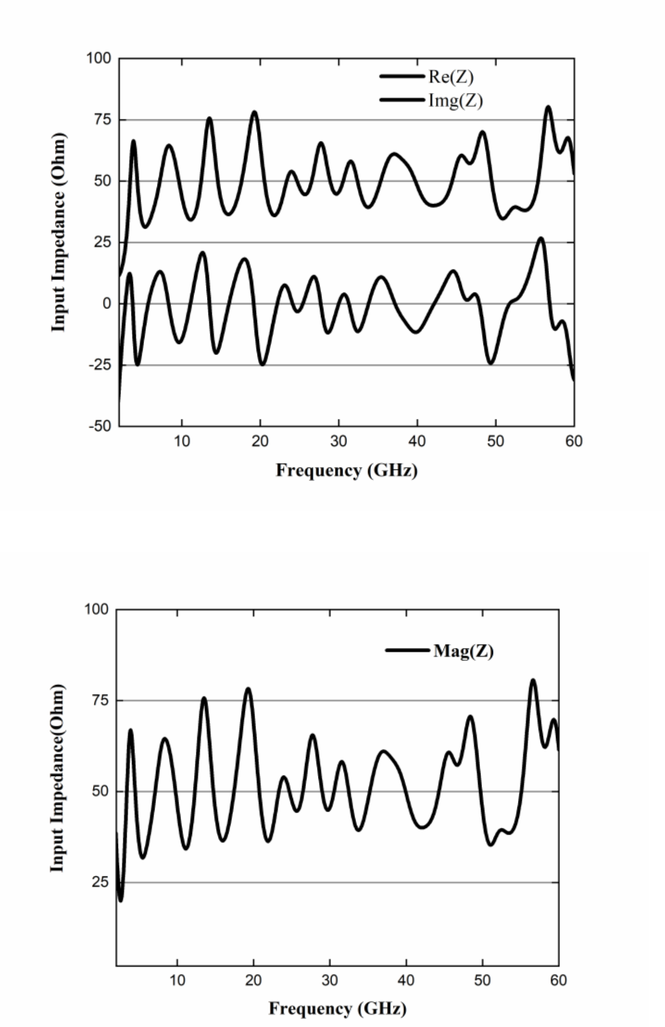

Fig. 11. Suggested SWB antenna's input impedance: (a) Real; (b) imaginary part; (c) magnitude.

V. CONCLUSION

A SWB antenna has been designed by making a cut in the form of a crescent moon into the antenna. This proposed antenna is covering a large range of frequencies, from 2.88 GHz all the way up to 60 GHz, and it only contains a single notched band. Because it has a wider frequency range, the antenna can be used for UWB, X, Ku, K and Ka-band. The antenna also has a peak gain of 7.74 dB, a maximum radiation efficiency of 96.55%, and an omnidirectional radiation pattern.

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