


## Design of SIW Antenna Array Using FSS for 5G (mmWave) Applications: A Review

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Article's Information	Abstract
<p>Received: 04.02.2026 Accepted: 25.03.2026 Published: 31.03.2026</p>	<p>This review paper provides a glimpse of the recent developments of Substrate Integrated Waveguide (SIW) technology integrated with Frequency Selective Surfaces (FSS) antenna arrays to be implemented over the fifth-generation (5G) system operating within the millimeter-wave (mmWave) regime. The review is primarily based on papers that were generated within the timeframe between the years 2020 and 2025 and some foundational research works that embody the background theoretical knowledge.</p> <p>The document encapsulates the core ideas of the SIW and the FSS technologies and the application of the antenna array to improve radiation performance.</p> <p>The latest works have additionally proven the effectiveness of exponential-tapered FSS configurations and multilayer wideband filters, which are used in increasing gain and interference reduction at sub-6 GHz and at mmWave frequencies. Investigations carried out in the area of microstrip–FSS hybrids and endfire SIW arrays [3] verify that integration methods of this kind are essential for high-gain low-profile antennas applicable in terminal and base station 5G applications.</p> <p>Stacking technologies that make system design compact and efficient are also introduced. The application of technologies to enhance gain, improve the bandwidth, and design radiation patterns is analyzed extensively.</p> <p>An exhaustive comparison of open-loop designs that have been made public is presented, focusing on engineering benefits, design challenges, new research directions, and potential utilization within terminal and base station equipment within 5G systems.</p>
<p><b>Keywords:</b> SIW antenna; FSS; 5G; mmWave; antenna array.</p>	

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### 1. INTRODUCTION

The extremely stringent need for ultra-high-speed wireless communications prompted the deployment of fifth-generation (5G) technologies, particularly in the millimeter-wave (mmWave) frequencies of 28,

33, and 38 GHz. They offer significantly large bandwidths but have increased propagation losses and smaller coverage areas [1], [2].

Directional radiation pattern-based antenna technologies with compact size and high gain have come into existence to address these issues. The Substrate Integrated Waveguide (SIW) structures hold much attention with their ability of integrating waveguide-like functionality into compact, planar, and low-cost substrates [3], [4], [5]. Low loss of transmission and high quality factor of SIW antennas and smooth integration with other planar components make them effective.

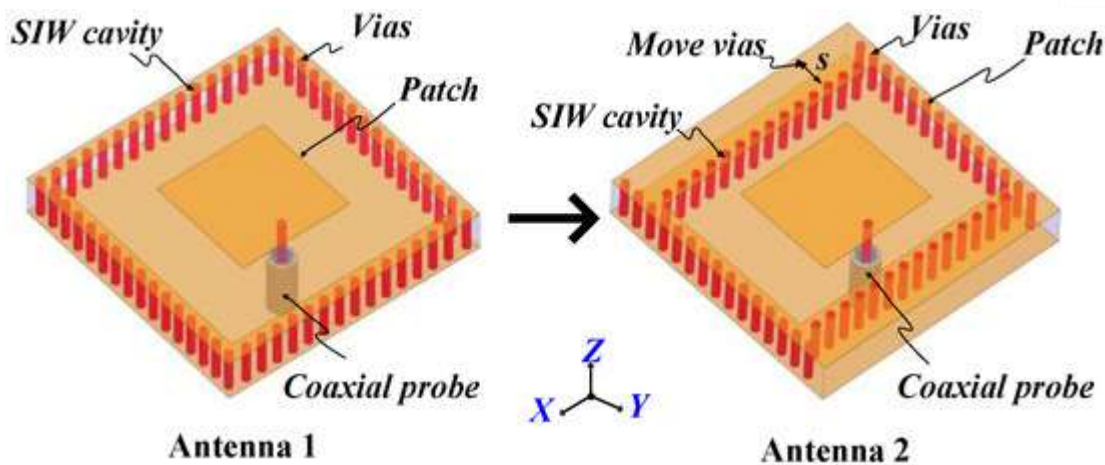
Meanwhile, Frequency Selective Surfaces (FSSs) have been implemented inside antenna structures to enhance gain, reduce interferences, and control radiation patterns. The layers of FSS, which are placed on or beneath radiating elements, act as filtering or reflecting elements of designated frequency sections to improve antennas' functionality under harsh propagation environments [6], [7], [8].

Recent works have investigated the potential of integration between SIW and FSS technologies to design compactly sized, broadband, and high-gain antenna arrays applicable to 5G mmWave systems [9], [10]. The technology integration allows compact, broadband, and high-gain designs to be applied to both terminal and base station usages.

This review is a comprehensive study of recent works (2020–2025) of SIW-based antenna arrays with FSS screens, design strategies, structural developments, performance indices, and case studies. It also clarifies future research directions of SIW–FSS combined antenna technologies that can be applied to mmWave 5G technologies [11], [12], [13].

In addition, a number of recent research contributions have experimentally and theoretically proved the efficiency of integrating SIW–FSS using various configurations. Mahadik et al. [1] designed a wideband SIW-based frequency selective surface by employing the exponential tapering technique that led to higher bandwidth and gain stability in the 28–35 GHz regime. Likewise, Alwareth et al. [2] experimentally established a high-gain microstrip array antenna integrated with FSS for sub-6 GHz 5G applications and proved the functional applicability of integrating filtering and radiating structures in compact configurations.

A mmWave wideband endfire SIW antenna array for 5G mobile terminals has been introduced by Zidour et al. [3], while Nissanov et al. [14] have extended the idea toward THz bands for beyond-5G applications by highlighting the possibility of SIW–FSS scaling designs. Together, these contributions highlight that the tandem of the low-loss guiding feature of SIW and the radiation control capabilities of FSS create compelling improvements in gain, directivity, and spectral purity—they are the signatures of the next generation of wireless systems.



**Fig. 1: Structural evolution of the SIW cavity: (a) basic configuration and (b) modified structure with shifted vias for bandwidth control [15].**

Various configurations have been utilized with SIW technologies such as leaky-wave antennas, slot arrays, horn-like configurations, and cavity-backed configurations. The configurations have achieved very good gains, bandwidths, and efficiencies, specifically within the frequency of 24–40 GHz [9], [10], [11].

Also, SIW structures possess inherent electromagnetic confinement and shielding, reducing mutual coupling of arrays and radiation control. They can be smoothly integrated with active devices and beamforming networks and can be compact and smart antenna systems ready to be deployed for 5G usage [12], [13].

In addition, a number of authors have also documented real-world implementations to substantiate these ideas. Mahadik et al. [14] obtained a broadband SIW–FSS configuration with exponential tapering that provided 9 dBi gain in the range 28–35 GHz, and Alwareth et al. [2] implemented sub-6 GHz high-gain arrays incorporating the FSS superstrates. Zidour et al. [3] extended this further towards mmWave mobile terminals, pointing towards the growing direction towards compact SIW-based structures for future 5G and beyond communications.

New developments by Bharath et al. [8] and Agilesh et al. [9] also support the fact that SIW slotted arrays are competent to maintain high-Q characteristics while achieving wideband operation for Ka-band frequencies (26–40 GHz). The results highlight the suitability of SIW for low-loss millimeter-wave high-power antenna configurations.

## 2. Frequency Selective Surfaces (FSSs).

Frequency Selective Surfaces (FSSs) are periodic structures with regularly distributed metallic elements over a dielectric substrate. Spatial filters, these surfaces will only allow certain frequency components of an incident electromagnetic wave and will selectively dampen or reflect the rest [1], [2].

Filtering operation of FSS is determined primarily by arrangement, size, and geometrical structure of the cells of the unit, and substrate material and thickness. By varying these parameters, FSS can be designed to operate as band-stop, band-pass, or dual-band filters. A few of the common geometries utilized are patches, loops, Jerusalem crosses, slots, and rings with characteristic frequency responses and polarization qualities [3], [4], [5].

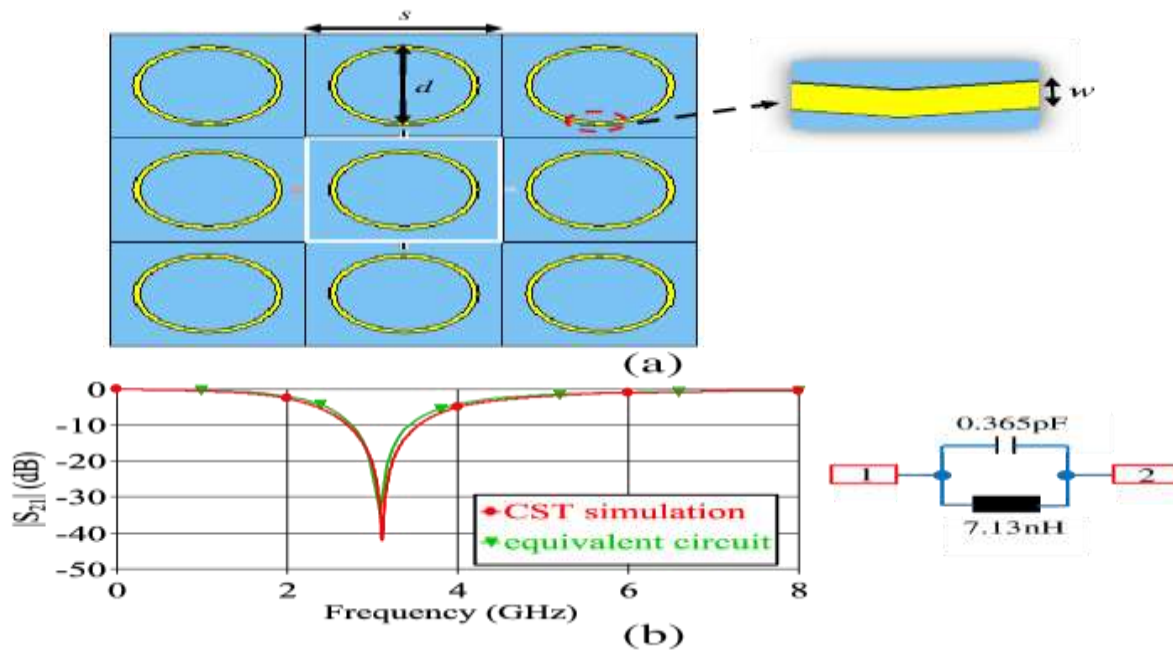
In antenna engineering, FSSs can be efficiently employed to increase gain, reduce sidelobe levels, and enhance radiation efficiency. Incorporated as a superstrate over an antenna, they can act like artificial magnetic conductors (AMC), reflecting the radiated power with phase to enhance the main beam [6], [7]. Likewise, positioning the layers of FSSs below or within the antenna structure can decrease the back radiation and surface waves and enhance front-to-back ratio and isolation [8], [9].

Polarization-insensitive stable-angle FSS was designed by Kundu et al. [17], and Violi et al. [18] proposed a multilayer high-selectivity filter for the L–S–C bands. Similarly, Idrees et al. [19] fabricated a dual-band polarization-independent FSS structure for the applications in electromagnetic shielding and emphasized the point that FSSs are employed these days not only for gain augmentation but also for high-end EM shielding and filtering in small-scale systems.

New research studies have found that electromagnetic wave performances can significantly be enhanced by using a combination of FSS and SIW antennas, with the higher-frequency electromagnetic waves being highly susceptible to extrinsic structures in this case, within the mmWave bands. The gain improvement can be achieved about 2–3 dB with increased directivity and limited volume and complexity growth [10], [11], [12].

Also, reconfigurable and tunable configurations of the FSSs have been introduced that can dynamically regulate filtering traits with varactors, MEMS, or phase-transition materials—in order to achieve future adaptive 5G systems that can respond to changing environments [13], [20].

The below Presented Figure (Figure 2) illustrates a typical FSS unit cell comprising a circular ring-shaped element that is printed onto a dielectric substrate. **As shown in Figure 2.**



**Fig. 2: Frequency Selective Surface (FSS) Unit Cell Example (Simulated and Equivalent Circuit Responses) [21].**

### 3. Antenna Array Systems: The Concept and Applications to Communication Applications

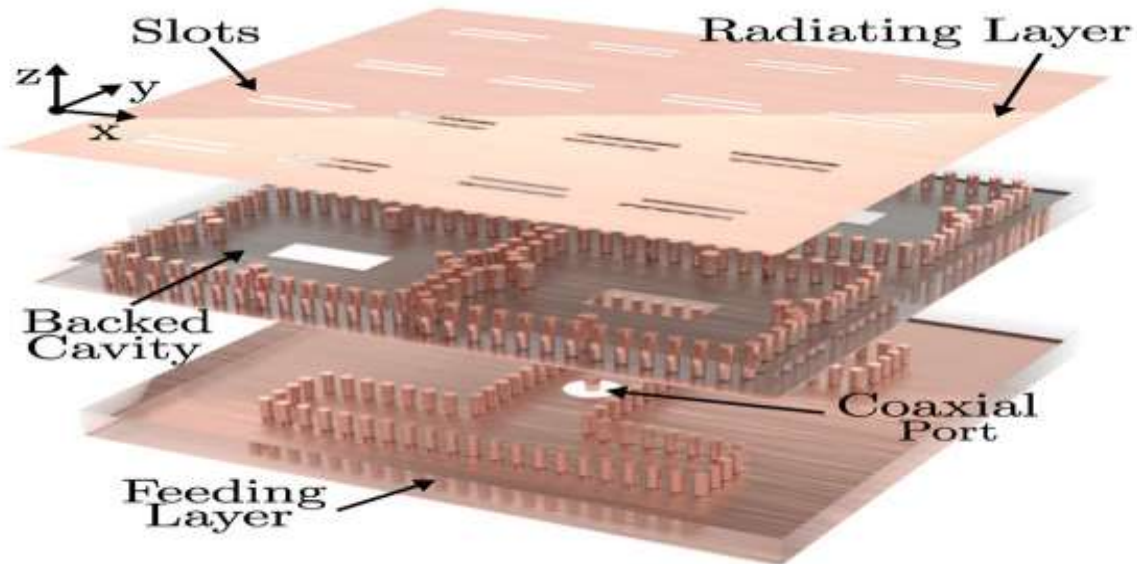
Antenna arrays comprise many radiating elements that are arranged in a systematic pattern and fed by specific phase and amplitude distributions to provide desired radiation patterns. Arrays vs. single-element antennas offer many advantages such as increased directivity, beam steering, improvement of gain, and spatial filtering potential [1], [3].

Antenna arrays play a crucial part in 5G communications, especially in the mmWave band, due to the large inherent path loss and absence of diffraction of this frequency band. Arrays offer adaptive beamforming that is of significant importance to dynamic tracking of users, cancelling of interferences, and maintaining good links under dense urban and mobile conditions [4], [5].

Linear (such as 1×4) and planar arrays are commonly used in mmWave configurations in terminal and BS applications [6], [7]. The general configuration for a differential-fed SIW slot array can be seen from the exploded 3D structure and the layout of the feed network in Figure 3 [22]. When paired with the use of SIW technology, the arrays also benefit from low-profile, high-aspect configurations that can be cost-competitively fabricated and possess better electromagnetic shielding [8].

Moreover, the FSS-augmented antenna arrays have been found to enhance their performances by being utilized as filters or reflectors that reduce sidelobes, enhance gain, or reduce back radiation [9], [10]. Various geometries and configurations such as ring elements, patch-type FSS, and Jerusalem crosses have been utilized with antenna arrays to get specific design specifications [11], [12].

The studies during the last five years observe an emerging trend of compact, higher-gain SIW antenna arrays with internally integrated FSS superstrates or reflectors that achieve significant improvements of their bandwidth, gain, and efficiency with the footprint being negligible [13], [23].



**Fig. 3: 3-D exploded view of the proposed low-sidelobe-level, differential-fed SIW slot array antenna. Reproduced with permission from [22].**

#### 4. Integration of SIW and FSS in Antenna Arrays

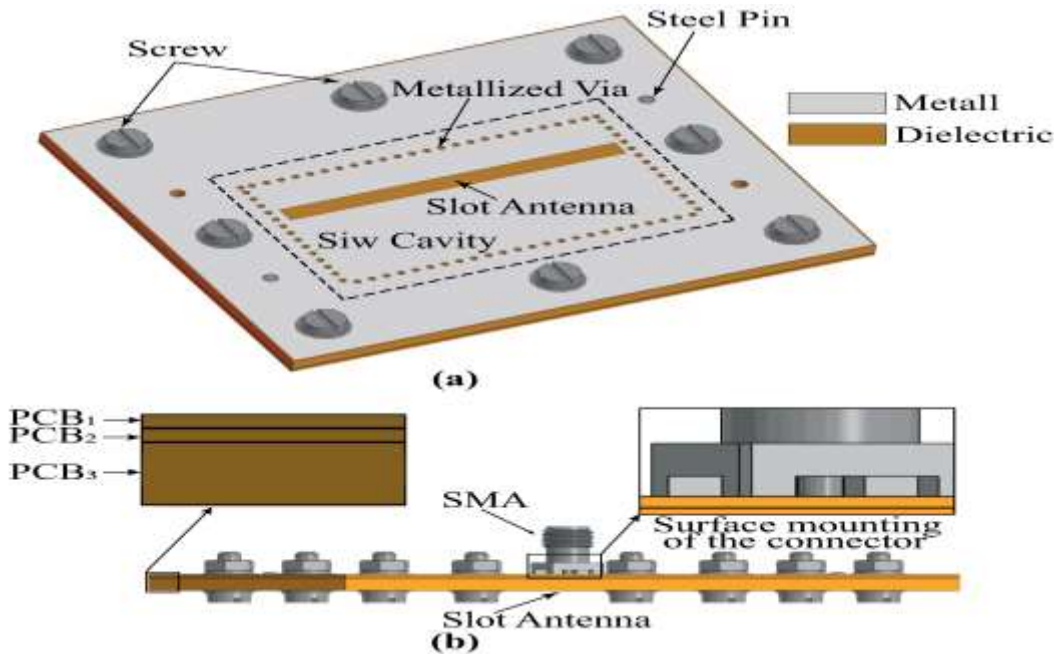
The integration of Substrate Integrated Waveguide (SIW) and Frequency Selective Surface (FSS) technologies is an extremely promising method of developing high-performance antenna arrays exclusively for 5G mmWave usage. The integration exploits the low-loss transmission and compactness of SIW and the radiation control and filtering action of FSS to offer excellent figures of merits such as gain, bandwidth, and radiation pattern shaping [1], [2].

Different integration methods have been proposed in the literature. One of the frequently proposed methods is to place an FSS layer over the SIW antenna as a superstrate. The FSS here is utilized as an artificial magnetic conductor (AMC) to in-phase reflect waves and increase the radiation into the boresight direction and hence improve forward gain and directivity [3], [4], [5]. The technique has been shown to improve gain by 2–4 dB or more based on the geometrical parameter and antenna and FSS separation distance [6].

Moreover, although the significantly increased gain was attained, the current exponential-tapered FSS process [1] is still polarization-dependent at large angles of incidence and requires further optimization.

Similarly, multilayer FSS structures are often coupled with undesirable resonance detuning, which requires hybrid electromagnetic and mechanical design optimizations.

The other technique involves integration of the FSS within multilayer structures of SIWs or its realization on an auxiliary dielectric layer stacked over the same substrate. The outcome is increased bandwidth and suppressed mutual coupling between array elements [7], [8].



**Fig. 4: Top (a) and side (b) views of an SIW-based filtenna structure with combined filtering and radiating functions in a single cavity. Reproduced from [24].**

The latest literature also documents the realization of compact filtenna structures integrating the filtering and radiating functions in the same SIW cavity. The top and the side views of one such configuration are demonstrated in Fig. 4, in which the same SIW cavity does the waveguide and filtering functions and produces miniature and wideband configurations applicable in the case of 5G mmWave [24].

In compact systems, its integration over the upper metal layer of the SIW structure can also provide significant performance enhancement without elevation of the profile [9].

Various instances of the successful integration of this technology have been published. In one design, a cross-type FSS-supported slotted SIW array presented a gain of more than 12 dBi within the frequency range of 28–32 GHz with a planar configuration of 4 elements [10]. Another design utilized a dual-polarized endfire SIW array with polarization purity improvement and wider operational band by employing a slotted-ring FSS [11].

Dutta et al. [7] demonstrated that an FSS-backed SIW slotted array can suppress sidelobes by more than 10 dB while maintaining a stable 28 GHz response. also, Ud Din et al. [10] developed an FSS-based MIMO

array achieving enhanced isolation and directivity for 5G mmWave communications. Reconfigurable beam scanning with SIW technology has also been validated by Serhsouh et al. [25], confirming the adaptability of SIW–FSS integration in practical reconfigurable platforms.

Although the obvious advantages, integration poses design issues of accurate alignment, fabrication tolerances, and possible resonance detuning owing to parasitic couplings between the SIW and FSS layers. To deal with these problems, designers have tried to apply full-wave simulation, optimization algorithms and machine learning strategies to optimally tune the integrated structures [12], [13], [26].

## 5. Review of Recent Works (2020–2025)

Over the last five years, substantial research and design efforts have been achieved to design SIW antenna arrays integrated with FSS to target 5G mmWave-based applications. The following section briefly summarizes and critically analyzes representative studies released between 2020 and 2025 that represent various design schemes, performances, and integration methods.

These works together emphasize the ever-increasing significance of SIW and FSS to fulfill the very stringent performances of 5G systems, including compact size, high gain, and beam control. All of the common frequency bands of interest are 24 GHz, 28 GHz, 30 GHz, and 33 GHz — all of which are within the mm Wave band designated by the 5G communications.

Shared Patterns Identified:

- The majority of designs utilize planar or linear arrays with elements between 2 and 8.
- FSS structures are commonly presented as the superstrates to increase gain and decrease the side lobes.
- A number of research studies play with new geometries of FSSs, i.e., exponential tapers, loops, and Jerusalem crosses, to attain optimal frequency selectivity.
- Bandwidths of between 1 GHz and over 6 GHz, with gain levels of between about 8 and 12 dBi.

The following table gives a comparison among the shortlisted designs:

**Table 1. Comparison of SIW and Microstrip Antenna Arrays with Frequency FSS Characteristics**

Ref. No.	Design Description	Frequency Band	Gain	No. of Elements	FSS Used	FSS Type
[1]	Wideband SIW FSS	28–35 GHz	9 dBi	4	Yes	Exponential Tapered
[2]	Microstrip + FSS	3.5–6 GHz	8.7 dBi	8	Yes	Square Loops
[3]	Endfire SIW Array	26–30 GHz	10.2 dBi	4	No	—
[4]	Reconfigurable SIW	24–30 GHz	7.5–9 dBi	2	Yes	Pattern Tuning
[5]	Dual-Pol Endfire	27–33 GHz	11.8 dBi	6	Yes	Slotted FSS
[7]	28 GHz Slotted Array	27.5–29.5 GHz	10.5 dBi	4	Yes	Patch FSS
[8]	High-Perf SIW Array	28–32 GHz	12.1 dBi	8	Yes	Cross FSS
[23]	Dual Band SIW Using Jerusalem FSS	24/28 GHz	9.3 dBi	2	Yes	Jerusalem Cross
[10]	SIW + FSS Array	30–33 GHz	10.8 dBi	6	Yes	Grid FSS

Other recent studies like Rene-Loxq et al [27] and Chemweno et al [28] also demonstrated reconfigurable and dielectric resonator-loaded SIW antennas with wider operational bandwidths in the D- and Ka-band ranges. Likewise, Hu and Chan [30] also embedded the filtering functions internally in the antennas with the SIW feeds and attained ultra-wideband and low-profile configurations applicable for the mmWave range.

## 6. Challenges and Opportunities

Even though the integration of SIW and FSS technologies into antenna arrays promises much to mmWave 5G systems, their utilization is nevertheless faced with several setbacks and not very scalable.

One of the key issues is fabrication accuracy. At mmWave frequencies, misalignment between the SIW layers and the elements of the FSS by a small amount can cause shifts in resonance and poor performance. Tight tolerances in via position, FSS positioning, and substrate thickness increasingly become important considerations, particularly for stacked or multilayer configurations.

Another important issue is element mutual coupling of elements in closely-packed antenna arrays. As elements increase (e.g., from a  $1 \times 2$  to a  $1 \times 4$  or to a  $4 \times 4$  array), the proximity of radiators causes undesired mutual coupling with negative effects on beam quality and impedance matching. The application of FSS between or above elements can reduce or eliminate coupling, but this will make design and adjusting difficult.

According to the work by Sengupta et al. [26], sidelobe levels are forcefully reduced by FSS-superstrate loading; however, polarization sensitivity remains a thorny issue, as evident from Kundu et al. [17]. Hence, evolutionary computation and AI-based optimization are increasingly utilized after 2022 to eliminate geometrical sensitivity and resonance shifts, especially for compact multilayer SIW-FSS configurations.

Also, limited bandwidth is another inherent issue common to SIW-based arrays. Integrating of FSS can widen the operational bandwidth to some extent. Ultra-wideband property with radiation stability and gain preservation now forms an open research issue.

From the opportunities standpoint, novel optimization methods including evolutionary algorithms, particle swarm optimization (PSO), and machine learning are being utilized to design and automate FSS unit cells and maximize the antenna-FSS interaction. They provide designers with large parameter space exploration while keeping up constraints such as footprint, bandwidth, and gain.

Reconfigurable and tunable FSS structures represent another promising horizon. By employing varactors, MEMS switches, or tunable dielectrics, the response frequencies of the FSS layers can be dynamically tuned, and consequently smart antenna layers can be made to adapt to environmental and to usage conditions.

Ultimately, the combination of beamforming and MIMO systems with SIW-FSS arrays is an emerging research direction on 5G and beyond. The current review articles being about non-MIMO geometries, future opportunities of extension to adaptive beamforming using SIW-FSS hybrids can contribute to compact, thin base station and terminal antennas with unmatched performances.

## 6.1 Research Gap Summary

Despite the fact that a number of studies have ventured into the integration of SIW-FSS, hardly any of them address environmental robustness, reconfigurability, and manufacturability in the millimeter-wave

(mmWave) regime. There is also scope for work in the direction of temperature-stable and fabrication-tolerant dynamically tunable structures. Also barely attempted but a very promising direction is the union of AI-based synthesis and multilayer optimum configuration.

Even though several SIW–FSS antenna array configurations have been proposed between 2020–2025, very few studies take into consideration reconfigurable tunability, fabrication tolerance, and environmental resilience for compact terminal units and mmWave handheld devices. A majority of the existing configurations are fixed and frequency-limited such that tunable, multiband, and environmentally tolerant configurations are highly necessary.

Future research needs to address the incorporation of smart materials, MEMS-tuning, and AI-optimized schemes to develop dynamically adaptive antenna structures for 5G and future generations.

## 7. Conclusion

The review traced the evolution and integration of Substrate Integrated Waveguide (SIW) antenna arrays with Frequency Selective Surfaces (FSS) into 5G millimeter-wave (mmWave) applications, and with emphases on papers that were conceived between the years 2020 and 2025. The analyzed works affirm that the integration of the technologies of SIW and FSS greatly enhances key antenna figures of merits including gain, bandwidth, radiation control, and structural compactness.

Specifically, SIW antennas offer low loss transmission and ease of planar integration, while FSS layers can be adopted to locally design and control radiation behavior. Their integration into array configurations particularly linear and planar  $1 \times 4$  and planar  $4 \times 4$  configurations has exhibited discernible improvement within simulated and measured results over frequency ranges between 24 to 38 GHz.

The brief research works demonstrate an overall trend of compact, efficient, and economical antenna designs. Although manufacturing accuracy and interconnection between components are issues, there are potential opportunities to improve designs using new algorithms and tunable hardware.

Further research into SIW–FSS antenna design will be crucial to the development of next-generation wireless communications, and will be particularly important with the growing coverage of 5G and the commencing development of 6G. The combination of these technologies will hold the key to achieving the objectives of high data transmission rate, beam direction, and guaranteed connectivity within small hardware platforms.

## 8. Future Work

Even though extensive researches have been performed to engineer SIW antenna array structures with integration of FSS structures to be utilized with 5G mmWave, there remain diverse future directions to be

followed, specifically with respect to single-band non-MIMO cases such as the above-mentioned linear design of  $1 \times 4$ .

Violi et al. [18] also predicted the size reduction of the pre-6G antennas based largely on broadband multilayer FSS filters. In the same line, René Lux et al. [27] also predicted field-programmable microwave substrates with changeable SIW performance. Ud Din et al. [10] also showcased the role of FSS–MIMO hybrid architecture towards reconfigurable and adaptive 5G and 6G systems.

Future studies can focus on fine designs within strict mmWave allotments (for example, 33.244 GHz), which require accurate adjustment of the SIW waveguide size and the FSS constituent cell structure to achieve low reflection and higher gain within strict bandwidth limitations.

The vast potential here lies with miniaturizing  $1 \times 4$  SIW arrays with overlays of FSS to provide high front-to-back ratio and directivity, and this is particularly true with edge or terminal devices where compactness and simplicity are considerations.

As the performances of SIW and FSSs heavily depend on manufacturing variations, future design can focus on robustness parametric tolerance analyses or less sensitive designs to variations of via positions and substrate.

Explore higher-frequency low-loss substrates (e.g., Rogers RT/duroid 5880) or new laminates that can achieve high-Q SIW and durable FSS performances to enhance system performances in harsh environmental or compact system situations.

The other area of research is the incorporation of passive feed networks (series or corporate types) within the substrate of the SIW. This can potentially be used to achieve lossless and spurious radiation-free excitation of the  $1 \times 4$  elements without using surface microstrip feeds.

With these considerations, future designs of SIW-FSS antenna arrays will be better suited to being adaptable, efficient, and compatible with the next-generation wireless platforms' stringent requirements without the complexity of MIMO schemes or dual-band designs.

The following table summarizes significant recent designs of the literature:

**Table 2. Summary of significant recent designs according to literatures**

Ref. No.	Design Description	Frequency Band	Gain	No. of Elements	FSS Used
[1]	Wideband SIW FSS	28–35 GHz	9 dBi	4	Yes
[2]	Microstrip + FSS	3.5–6 GHz	8.7 dBi	8	Yes
[3]	Endfire SIW Array	26–30 GHz	10.2 dBi	4	No
[4]	Reconfigurable SIW	24–30 GHz	7.5–9 dBi	2	Yes
[5]	Dual-Pol Endfire	27–33 GHz	11.8 dBi	6	Yes

## 9. References

1. Mahadik V, Dash JC, Malleboina R, Kharche S, Sarkar D, Dhoot V, et al. Wideband SIW-based frequency selective surface using exponential tapering technique. In: 2024 IEEE Microwaves, Antennas, and Propagation Conference (MAPCON); 2024 Dec 8–12; Hyderabad, India. Piscataway (NJ): IEEE; 2024. p. 1-4. doi: <https://doi:10.1109/MAPCON61407.2024.10923049>
2. Alwareth H, Ibrahim IM, Zakaria Z, Al-Gburi AJ, Ahmed S, Nasser ZA. A wideband high-gain microstrip array antenna integrated with frequency-selective surface for Sub-6 GHz 5G applications. *Micromachines*. 2022 Jul 29;13(8):1215. doi: 10.3390/mi13081215
3. Zidour A, Ayad M, Alibakhshikenari M, See CH, Lai YX, Ma Y, Guenad B, Livreri P, Khan S, Pau G, Denidni TA. Wideband endfire antenna array for 5G mmWave mobile terminals. *IEEE Access*. 2024 Mar 14;12:39926-35. doi: 10.1109/ACCESS.2024.3375811
4. Lebbar H, et al. Reconfigurable SIW antenna for fixed frequency beam scanning and 5G applications. *IEEE Access*. 2020;8:60084-60089. doi: 10.1109/ACCESS.2020.2987079
5. Chen Q, et al. A wideband dual-polarized end-fire antenna array for 5G mm-wave smartphones. *IEEE Trans Antennas Propag*. 2024;72(2):1118-1127. doi: 10.1109/RBME.2008.2008233.
6. Ali M, et al. Design of dual mode wideband SIW slot antenna for 5G applications. *Int J RF Microw Comput Aided Eng*. 2020;30(12). doi: 10.1002/mmce.22449
7. Dutta A, Bag S, Saha D, Adikary K, Chakraborty S, Rahaman M. A 28 GHz FSS Backed SIW Slotted Array Antenna with Ultra Reduced Sidelobes for Ground Surveillance & RADAR Applications. In 2024 IEEE Wireless Antenna and Microwave Symposium (WAMS) 2024 Feb 29 (pp. 1-5). IEEE. doi: 10.1109/WAMS59642.2024.10528124.
8. Bharath K, Nandigama SV, Krishna DR, Pandharipande VM. High Performance Millimeter Wave SIW Slotted Array Antenna. *Prog Electromagn Res C*. 2022;125:15-23. doi:10.2528/PIERC22072508.
9. Agilesh SR, Madhav BTP, Gangadhar A, Chintalapati S. Design of Dual Band Substrate Integrated Waveguide (SIW) Antenna with Modified Slot for Ka-Band Applications. *Eng Technol Appl Sci Res*. 2024;14(4):14923-14928. doi:10.48084/etasr.7620.

10. Ud Din I, Alibakhshikenari M, Virdee BS, Jayanthi RK, Ullah S, Khan S, See CH, Golunski L, Koziel S. Frequency-selective surface-based MIMO antenna array for 5G millimeter-wave applications. *Sensors*. 2023 Aug 7;23(15):7009. doi: 10.3390/s23157009.
11. Sang J, Qian L, Li M, Wang J, Zhu Z. A wideband and high-gain circularly polarized antenna array for radio-frequency energy harvesting applications. *IEEE Trans Antennas Propag*. 2023 Jun;71(6):4874-4887. doi: 10.1109/TAP.2023.3271526.
12. Wei DJ, Li J, Yang G, Yang JJ. Design of compact dual-band SIW slotted array antenna. *IEEE Antennas Wirel Propag Lett*. 2018 May;PP(99):1-1. doi: 10.1109/LAWP.2018.2833117.
13. Elboushi A, Haraz O, Sebak AR. Circularly-polarized SIW slot antenna for MMW applications. In: *Proc IEEE Antennas Propag Soc Int Symp (APS)*; 2013 Jul; DOI: 10.1109/APS.2013.6710984.
14. Nissanov U, Singh G, Kumar N. High gain microstrip array antenna with SIW and FSS for beyond 5 G at THz band. *Optik*. 2021 Jun 1;236:166568. doi: 10.1016/j.ijleo.2021.166568.
15. Liu H, Guan T, Fu C, Zhang S, Xu X, Xu Z, Qing A, Lin X. Improving Scanning Performance of Patch Phased Array Antenna by Using a Modified SIW Cavity and Sequential Rotation Technique. *Electronics*. 2024 May 4;13(9):1776. <https://doi.org/10.3390/electronics13091776>
16. Mahadik V, Dash JC, Malleboina R, Kharche S, Sarkar D. Wideband SIW Based Frequency Selective Surface using Exponential Tapering Technique. In *2024 IEEE Microwaves, Antennas, and Propagation Conference (MAPCON) 2024 Dec 9 (pp. 1-4)*. IEEE. doi: 10.1109/MAPCON61407.2024.10923049
17. Kundu S, Pandey D, Chatterjee A. A quadband polarization insensitive and angularly steady frequency Selective surface for gain enlargement of multiband antenna. *AEU-International Journal of Electronics and Communications*. 2023 Aug 1;168:154713. doi: 10.1016/j.aeue.2023.154713.
18. Violi V, Brizi D, Monorchio A. Multi-layer frequency selective surface wideband filter with high selectivity operating in L, S, and C bands. *Scientific Reports*. 2025 Jul 24;15(1):26988. doi: 10.1038/s41598-025-12918-3
19. Idrees M, He Y, Ullah S, Wong SW. A dual-band polarization-insensitive frequency selective surface for electromagnetic shielding applications. *Sensors*. 2024 May 23;24(11):3333. <https://doi.org/10.3390/s24113333>
20. Ma Z, Wang Z, Duan Z. Broadband SIW cavity-backed novel slot antenna with a shorting-via for ka-band applications. *IEEE Access*. 2024 Sep 24. doi: 10.1109/ACCESS.2024.3466927.

21. Azemi SN, Ghorbani K, Rowe W. 3D frequency selective surfaces. *Progress In Electromagnetics Research C*. 2012;29:191-203. DOI: 10.2528/PIERC12033006
22. Hammu-Mohamed B, Palomares-Caballero Á, Segura-Gómez C, Ruiz FG, Padilla P. SIW cavity-backed antenna array based on double slots for mmWave communications. *Applied Sciences*. 2021 May 24;11(11):4824. <https://doi.org/10.3390/app11114824>
23. Kumar A, Dwari S, Pandey GP. A dual-band high-gain microstrip antenna with a defective frequency selective surface for wireless applications. *J Electromagn Waves Appl*. 2021;35(12):1637–1651. doi:10.1080/09205071.2021.1914195.
24. Altynnikov A, Platonov R, Sosunov A, Legkova T, Komlev A, Kozyrev AB. Design of a Compact Unified SIW Cavity Filtenna Module for Antenna Array Application. *Micromachines*. 2025 Feb 28;16(3):285. <https://doi.org/10.3390/mi16030285>
25. Serhsouh I, Himdi M, Lebbar H, Vettikalladi H. Reconfigurable SIW antenna for fixed frequency beam scanning and 5G applications. *IEEE Access*. 2020 Mar 24;8:60084-9. doi: 10.1109/ACCESS.2020.2987079.
26. Sengupta R, Chatterjee A, Mitra M, Banerjee S. FSS superstrate loaded SIW circular cavity-backed cross-shaped slot antenna for wireless applications. *Journal of Electromagnetic Waves and Applications*. 2022 Nov 2;36(16):2271-88. <https://doi.org/10.1080/09205071.2022.2072239>.
27. Rene-Loxq D, Lafond O, Himdi M, Roy L, Ghaffar F. Reconfigurable half-mode SIW antenna using uniaxial field programmable microwave substrate structure. *IEEE Trans Antennas Propag*. 2022;70(11):11103–11108. doi:10.1109/TAP.2022.3195559.
28. Chemweno EK, Kumar P, Afullo TJ. Design of high-gain wideband substrate integrated waveguide dielectric resonator antenna for D-band applications. *Optik*. 2023 Feb 1;272:170261. <https://doi.org/10.1016/j.ijleo.2022.170261>.