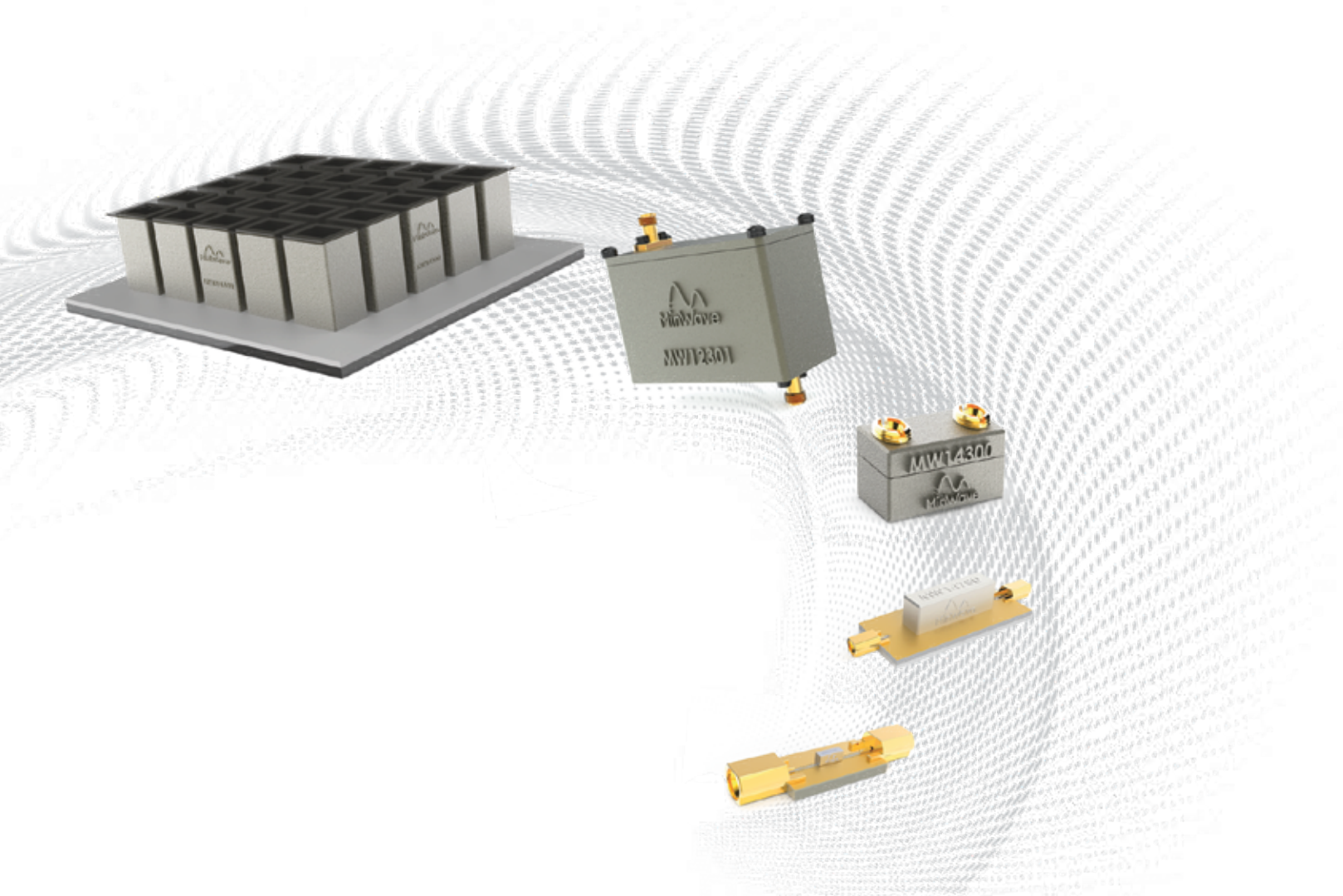
MinWave

Metamaterial RF front-end to reduce the cost per bit

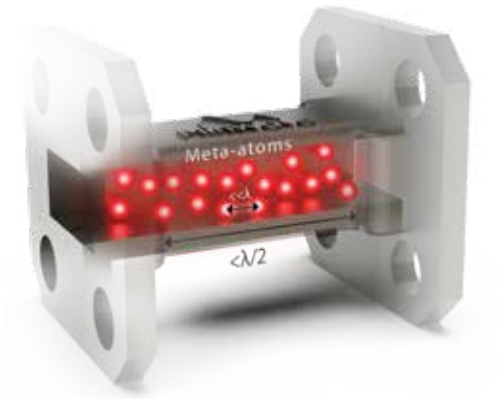


MinWave core technology

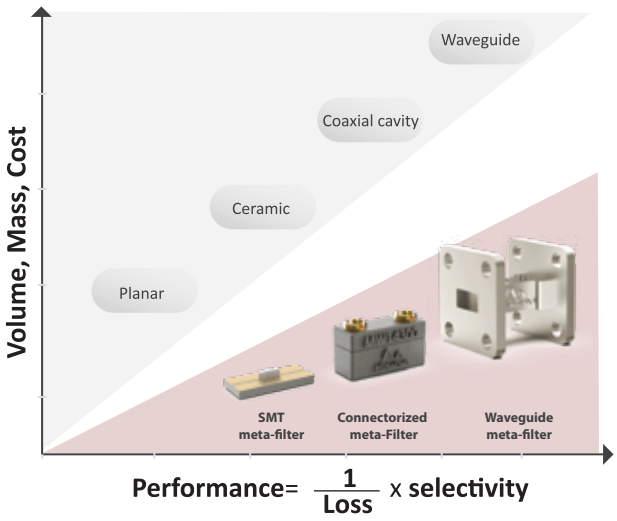
MinWave employs patented cutting-edge metamaterial wave engineering methods to develop ultra-compact, low-loss, and lightweight RF front-end (RFFE) solutions to reduce the cost/bit in Telecom and Satcom. We offer a wide range of custom and standard devices compatible with various interfaces, such as waveguide, surface mount, and coaxial ports.

MinWave meta-devices

MinWave designs and manufactures RF front-end solutions, such as filters, antennas, and filtering antennas, based on novel metamaterial wave engineering methods. The **MinWave** artificial structure can filter and radiate the waves in a deep subwavelength scale. It also provides sharp selectivity, high rejection level and wide band rejection. The **MinWave** low-loss miniaturized meta-waveguide devices and integrated systems offer a superior alternative to traditional filters, such as cavities, planar and ceramic filters, and antennas.



Minwave technology = $\underbrace{\varepsilon \leq 0 \text{ or } \mu \leq 0}_{\text{Sharp selectivity}} + \underbrace{\text{sub-}\lambda}_{\substack{\text{Miniaturized} \\ \text{low loss}}}$



MinWave products for telecom

1. **sub-6 GHz technology**
   a. Miniaturized base station filters
   b. 5G filtering antenna array
2. **5G FR2 technology (24-50 GHz)**
   a. Base station filter and antenna
   b. FR2 miniaturized consumer device filters
3. **P2P link RF front-end solutions**
4. **GPS anti-jamming receiver antenna**

Manufacturing

MinWave develops components and appropriate fabrication methods based on the application. We have experience in customizing SLM (metal 3d print), casting, and micromachining to fabricate devices to meet the telecommunication industry's needs. Furthermore, we are working with experienced partners to utilize the appropriate manufacturing method to provide integrated and low-cost RF front-end solutions for various applications.

MinWave RF front-end solutions

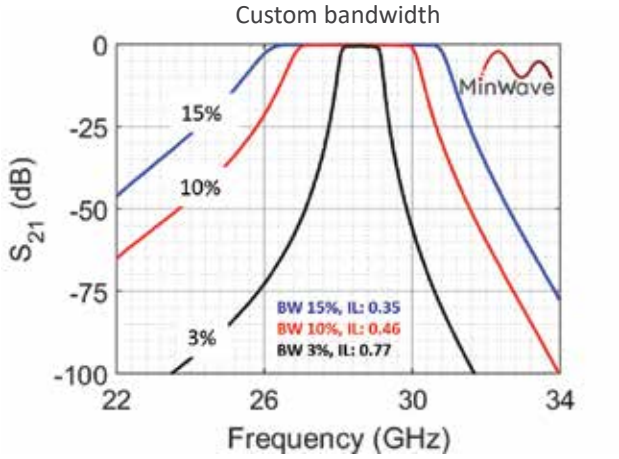
Customizable meta-filters

The metamaterial nature of **MinWave** filters enables customizable bandwidth (1–50%) while maintaining low insertion loss, very high-quality factor, and fixed sub-λ (miniaturized) total length of the filter. Furthermore, **MinWave** metamaterial designs introduce higher-order poles and a stack of zeros to regulate the selectivity without a considerable change in the footprint.

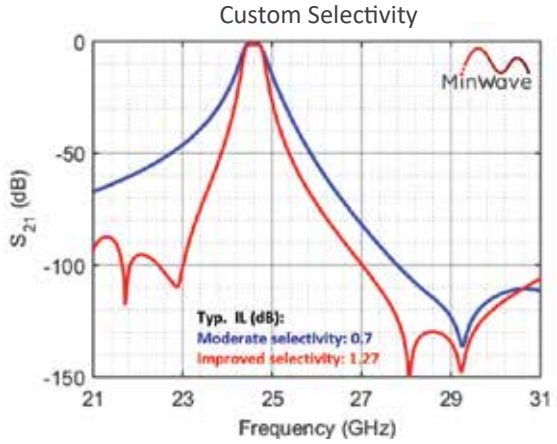
Key features:

- Ultra-small (sub-λ) footprint
- Customizable bandwidth (1 - 50%)
- Sharp roll-off and high selectivity
- High quality factor and low insertion loss

Custom bandwidth



Custom Selectivity



Connectorized and integrated RF components

MinWave has developed various connectorized solutions with various coaxial connectors and surface mount techniques (SMT). Furthermore, integrated meta-filters and antennas for lower loss and passive intermodulation risk are a must for modern high-quality systems. We have developed integrated meta filtering antennas to reduce the cost and increase the quality of the RF front-end.

Meta filtering antenna

SMP meta filter

SMT meta filter

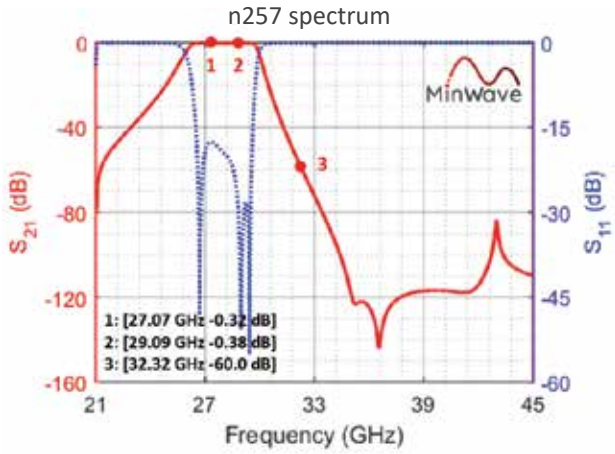
MinWave mm-Wave solutions for Telecom

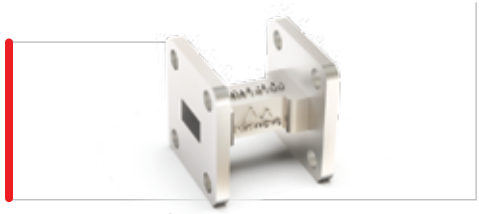
MinWave is addressing the challenges of mm-wave 5G wireless infrastructure and devices in an unparalleled manner. **MinWave** patented metamaterial wave engineering method allows us to produce low-loss and high-selectivity filters with a high level of rejection and wide stopband and seamlessly integrate them with antenna and the other parts of the RF front-end. Based on these promising features **MinWave** products are a superior alternative for conventional planar and LTTC devices, as well as the waveguide and coaxial cavity filters.

Waveguide filter and filtering antenna

MinWave designs and produces waveguide filters, from 1-40 GHz, with both rectangular and ridge waveguide ports having standard or custom flanges. Here, we introduce a few products for 5G mm-wave applications. **MW14115** is an exemplary miniaturized waveguide filter that operates at the n257 frequency band with standard WR28 waveguide ports. It provides a typical insertion loss of less than 0.5 dB across its passband and a minimum rejection of 80 dB in the rejection band. High-quality and compact filters allow the development of highly energy- efficient FR2 radios.

n257 spectrum



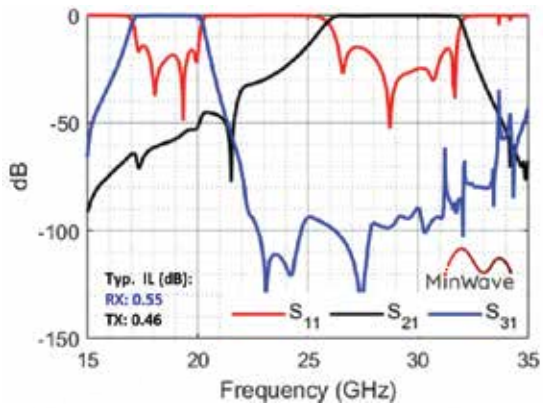


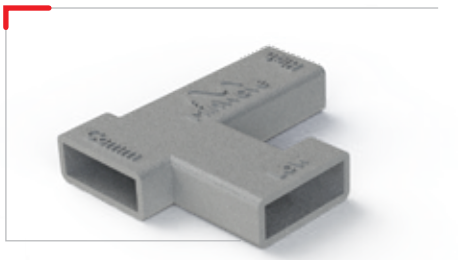
Waveguide filter

Waveguide diplexers

MinWave designs and produces different waveguide based component s for various usecase. Among them non-contigous diplexers for mm-wave play an important role in telecom and satcom infrastructure. **MW44200** is an ultra-compact diplexer for non-contiguous channels at the K band, developed based on our techniques.

K band diplexer spectrum

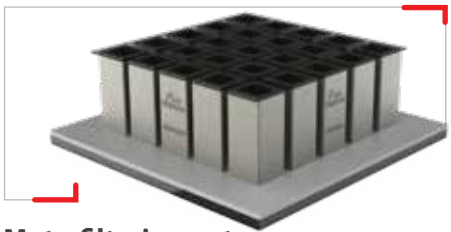




Non-contiguous diplexer

Filtering antenna

High quality and compact filters allow development of full metal, low-loss filtering antennas for 5G FR2.



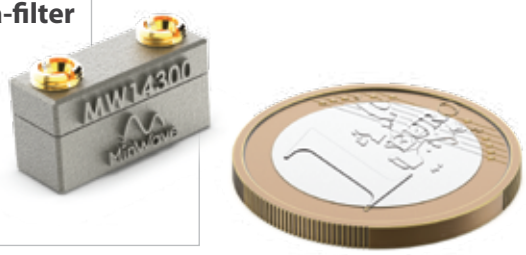
Meta-filtering antenna array

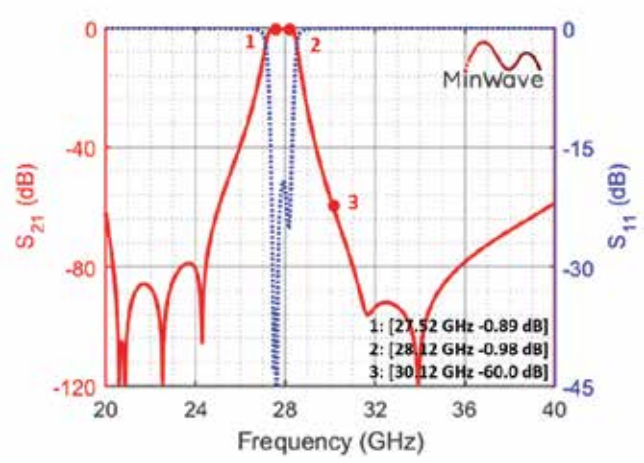
MinWave mm-wave device RF front-end solutions

Connectorized solutions

We have developed a connectorized version of metallic metamaterial filters with a smaller footprint, especially for telecommunications, without the need for an adapter from waveguide to coaxial ports. As in waveguide versions, the sharp roll-off of the **MinWave** filters can improve the spectral efficiency required by telecom operators. **MW14300** is an exemplary miniaturized bandpass filter with SMP connectors that operates at the n261 3GPP frequency band. Based on our diplexing technique, **MW44300** is designed as a novel connectorized version of the non-contiguous channels K band diplexer.

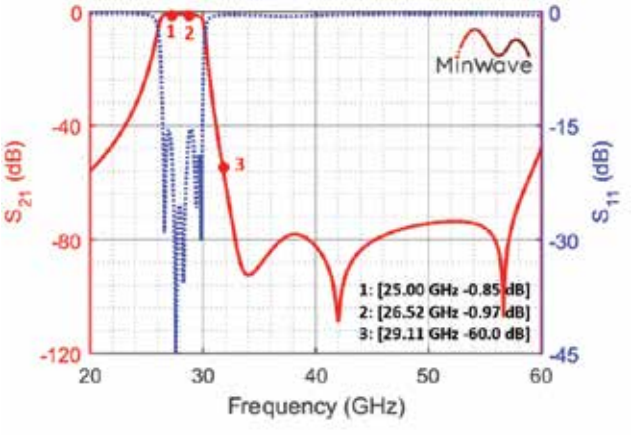
SMP meta-filter

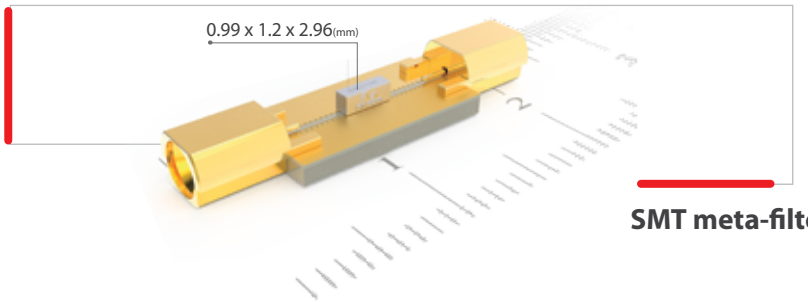




SMT meta-filters

MinWave is developing a novel version of SMT filters for 5G mm-wave devices with promising specifications. **MinWave** meta-filters are the smallest filters in the market, with a surface area of less than 6 mm ^{2}, while keeping the high quality of the filters. For instance, the n258 3GPP filter has IL<1·2 dB, beyond the current competitor technology's possibilities. Moreover, **MinWave** meta-filter has a very good out-of-band rejection for canceling higher order harmonies of PA. Our technology is CMOS compatible and is an alternative to LTCC and lumped CMOS filters for mm-wave





SMT meta-filter

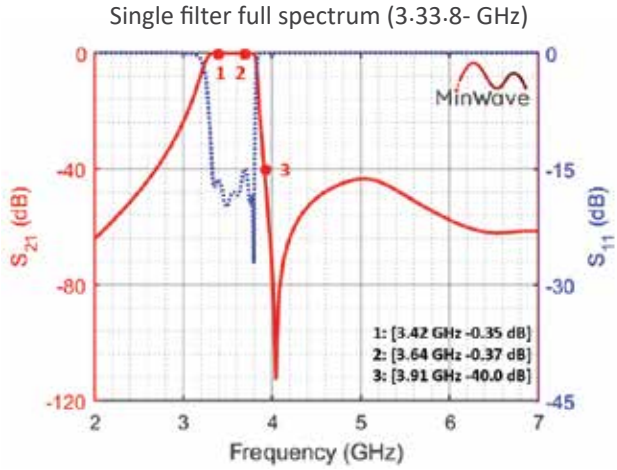
Sub-6 GHz MinWave Products for Telecommunications

Implementing low-loss, miniaturized, and highly-selective sub-6 GHz filters/antennas for 5G wireless devices and infrastructure is still a challenge that **MinWave** is proud to take on. We offer all metal low-loss and wide out-of-band rejection filters for 5G base stations to address all challenges and provide an alternative for lossy ceramic filters at a lower cost.

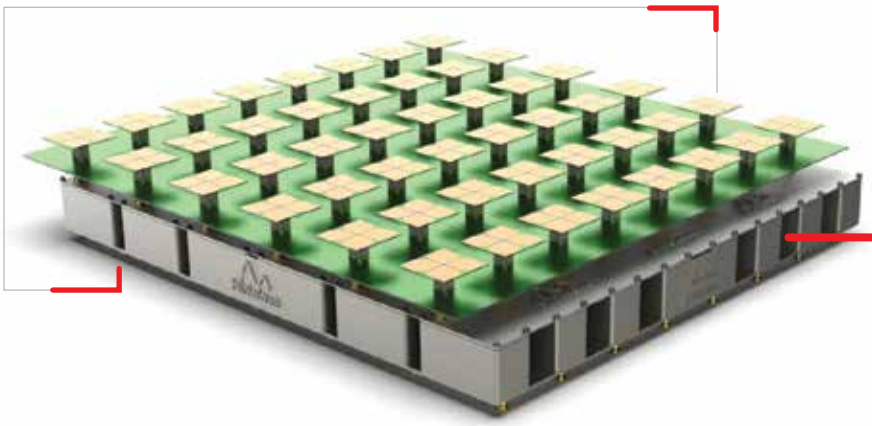
Integrated array of meta-filters for 5G BTS

This revolutionary RF front-end unit provides reliable connectivity at a fraction of the cost of alternative RF front-end units for sub-6 GHz 5G base stations with better RF specifications. With its advanced design and low-cost monolithic fabrication of the array of filters, this product is guaranteed to provide a high-throughput terminal. Plus, the lightweight and compact design of the array of filters makes it easy to install and reduces assembly time, costs, and loss.

Single filter full spectrum (3·33·8- GHz)



MinWave array of filters for 5G



MinWave BTS filter

Key features:

- All metal miniaturized low-loss filters
- Sharp roll-off to avoid interference with critical infrastructure
- Cheaper production cost relative to alternative technologies
- Wide rejection band to cancel higher harmonies of PA

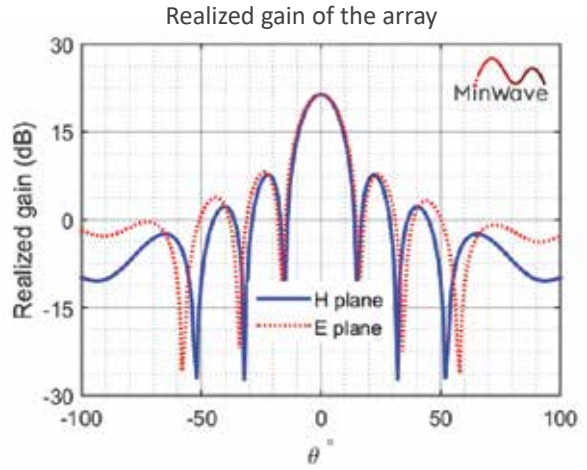
C-band reject filters

The new C-band 5G considerably increases the available bandwidth for the telecommunication industry, however, introduces interference risk to the traditional systems. **MinWave** offers the smallest sharp 5G reject filters for radar altimeters and traditional satcom receivers.

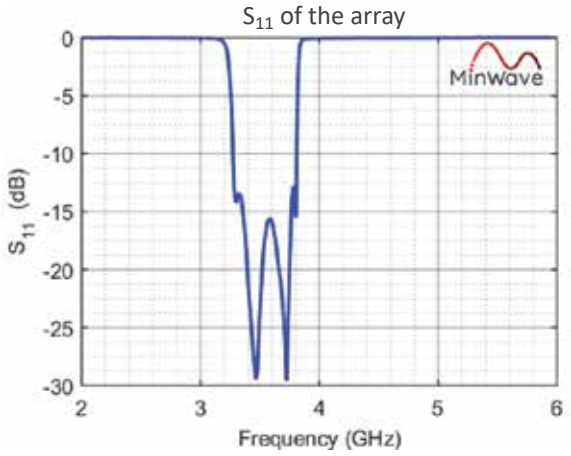
Meta-filtering antenna array

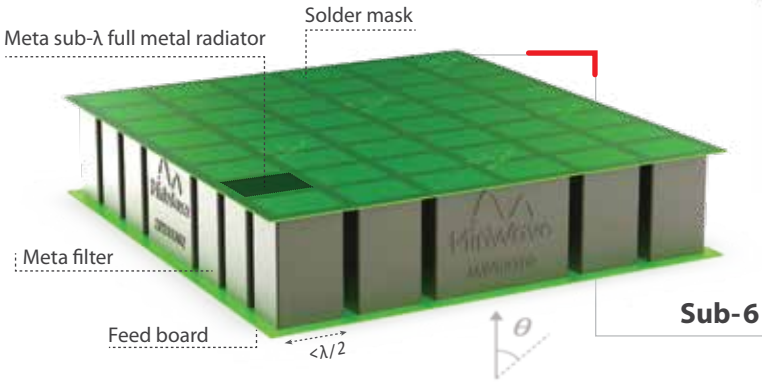
MinWave integrated filtering antenna is designed to provide superior performance in crowded wireless environments at C-band for FR1 base stations. Each antenna element in the array is monolithically integrated with the small meta-waveguide filter to reduce the cost and risk of PIM. It allows low loss, high spectral efficiency, high gain, and throughput in a small footprint (<λ/2xλ/2). It also provides sharp selectivity and high-level rejection as an alternative for coaxial cavity and ceramic filters that eliminates interference, while it can also radiate with high gain. The **MinWave** FR1 meta-filtering can be used with coaxial connectors or mounted on PCB with a small footprint.

Realized gain of the array



S_{11} of the array





Sub-6 GHz meta-filtering antenna

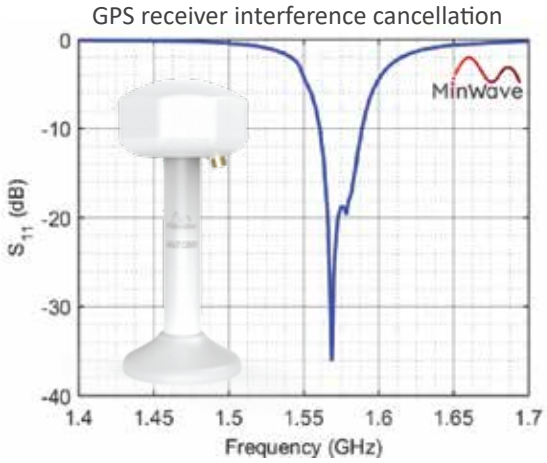
Anti interference GPS antenna

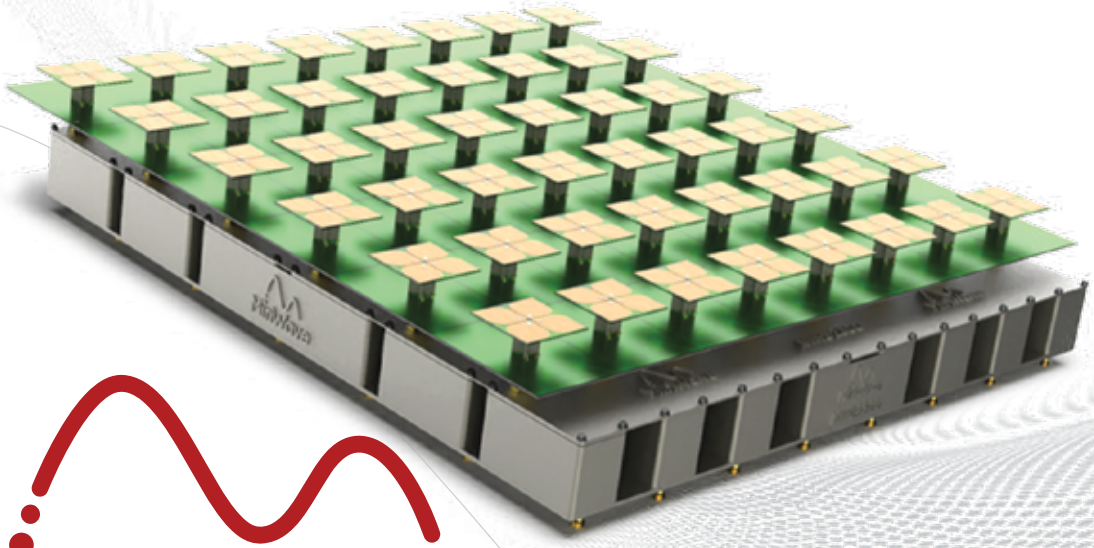
The Global Positioning System (GPS) plays a pivotal role in ubiquitous location-based services and also in time synchronization for the cellular network, especially in 5G wireless communication and security compromises are unacceptable. The metamaterial-based **MinWave** GPS receiver antenna helps consumers to avoid any system's vulnerability against deliberate or unintentional interferences. The rejection level (>30dB) of this passive and miniaturized device is close to costly and complex active arrays.

GPS antenna performance

Gain (dBi)	Efficiency (%)	HPBW (degree)	AR (dB)
8.4	> 95	> 55^0	< 3
Suppression (dB)	**Unwanted Signal Polarization**	**Unwanted Signal Azimuth Angle (Degree)**	**Unwanted Signal Elevation Angle (Degree)**
≥ 30 dB	Insensitive	0-360	< ±30

GPS receiver interference cancellation





MinWave

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