Valmont Telecom Insights
White Paper

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Low & Mid-Band RF Performance of Mid-Cell Concealments

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Executive Summary

As the telecom industry pushes forward with 5G and begins laying the groundwork for 6G, the importance of optimizing low- and mid-band frequencies remains critical. These frequencies support the foundation of 4G and 5G networks and are expected to remain in heavy use for years to come—especially with renewed spectrum auctions and reallocation of bands such as AWS-3 and C-band.

This white paper presents research and testing conducted by Valmont Telecom, through its small cell infrastructure brand ConcealFab, on the Radio Frequency (RF) performance of various concealment materials in low and mid-band frequency ranges. Through innovative test setups and antenna pattern analyses, the findings demonstrate that material choice dramatically affects transmission loss and network performance. Specifically, newer thermoplastics like clearWave S240 outperform traditional fiberglass reinforced polymer (FRP), offering significantly lower loss, reduced signal distortion, and improved antenna performance in mid-cell concealments.

The results not only inform engineering design but help mobile carriers, OEMs, and infrastructure partners maximize network efficiency and reduce interference. These insights become even more vital as the industry prepares for 6G, AI-driven network optimization, and expansion into non-terrestrial networks.

Background

Despite the general worldwide trend of deploying higher frequencies for telecommunications, the performance of antenna concealments at low and mid-band is more relevant than ever. These frequencies offer better building penetration and broader geographic coverage, making them indispensable for wide-area and suburban deployments. For example, much of Verizon's 5G coverage is anchored in C-band, while T-Mobile leverages low-band 600 MHz spectrum to expand rural reach.

Low and mid-band frequencies are also utilized in existing 4G and 5G infrastructure, providing a performance backbone that higher frequencies can't replace. In the U.S., spectrum between 700 MHz and 4.2 GHz is in daily commercial use—supporting mobility, public safety, and fixed wireless access. With AWS-3 (1695–2180 MHz) and C-band (3.98–4.2 GHz) under consideration for re-auctioning between 2025 and 2027, the relevance of these bands will only grow.

Since 2018, Valmont Telecom has led internal R&D projects focused on understanding material performance from 700 MHz up to 40 GHz. These efforts assess how concealment materials affect transmission loss and antenna patterns, especially when installed in the near-field of the antenna. Outcomes are compiled into a proprietary RF Material Selection Matrix, now central to the design of Valmont's concealment products, including macro site solutions and mid-cell poles.

Figure 1: Mid-Cell Pole

Concealment Basics

A concealment is an RF-transparent dielectric structure that houses or wraps around antennas, essentially acting as a second radome. The goal is to make the site visually discreet without compromising antenna performance. For effective concealment, the material should transmit radio waves with minimal reflection or absorption. This is influenced by the dielectric constant (relative permittivity) and loss tangent of the material.

Electrically thin materials—those less than 0.1 wavelengths thick—typically perform well. However, at higher frequencies, even common concealment materials can become electrically thick. In such cases, selecting a material thickness that aligns with half-wavelength resonance can maximize transmission. Because material properties at high frequencies are often unknown or vary with orientation, Valmont Telecom uses direct measurement of transmission loss across frequency ranges and distances to screen materials quickly and accurately.

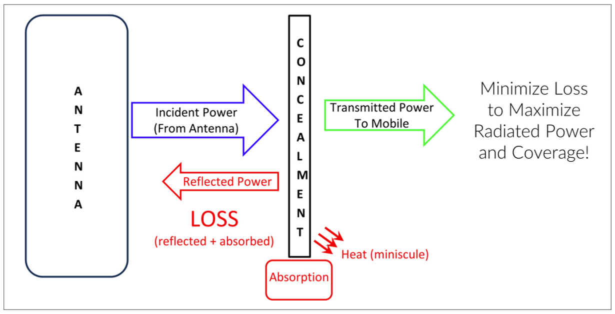

Figure 2: Conceptual diagram showing the interaction of radio waves with a concealment material. Reflected and absorbed power must be minimized to maximize the transmitted power.

Experimental Techniques

Far-field Transmission-Loss vs. Frequency

This test simulates an ideal RF environment, using anechoic chambers to eliminate interference. A material sample is placed between a transmitting and receiving antenna at a distance such that it does not interact with either. A vector network analyzer (VNA) measures power reduction as the signal passes through the material. Tests vary angles of incidence and wave polarization to reflect real-world variability.

Near-field Transmission-Loss vs. Frequency vs. Distance

Real-world antenna deployments place concealments in the near-field of the antenna, where interactions are more complex. Valmont Telecom developed a proprietary loss vs. distance vs. frequency (LvDvF) setup that places the material flush against the antenna and moves it outward in 1 mm increments (in the case for C-band) or in 25 mm increments (in case for low-band), capturing how loss changes across frequencies and distances. The results are plotted as "cyclone plots" which can be seen later in Figure 5, that reveal performance sensitivity.

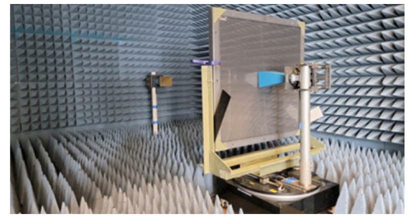

Figure 3: Near-field transmission-loss vs. distance vs. frequency (LvDvF) test set-up in anechoic chamber.

Antenna Patterns

Using real-world panel antennas in the 3.6 GHz range and phased arrays at 28 and 39 GHz, far-field antenna patterns are measured with and without concealments in place. This shows changes in main lobe gain, beamwidth, boresight error, and backlobe radiation. These metrics indicate the impact concealments have on network coverage and interference potential.

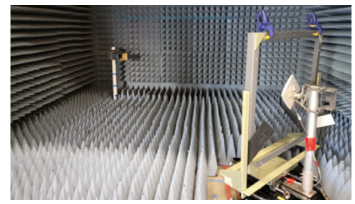

Figure 4: Antenna pattern testing, 3.6 GHz.

RF Performance Comparison: FRP vs. clearWave S240

CBRS / C-Band Results (3.4 – 4.2 GHz)

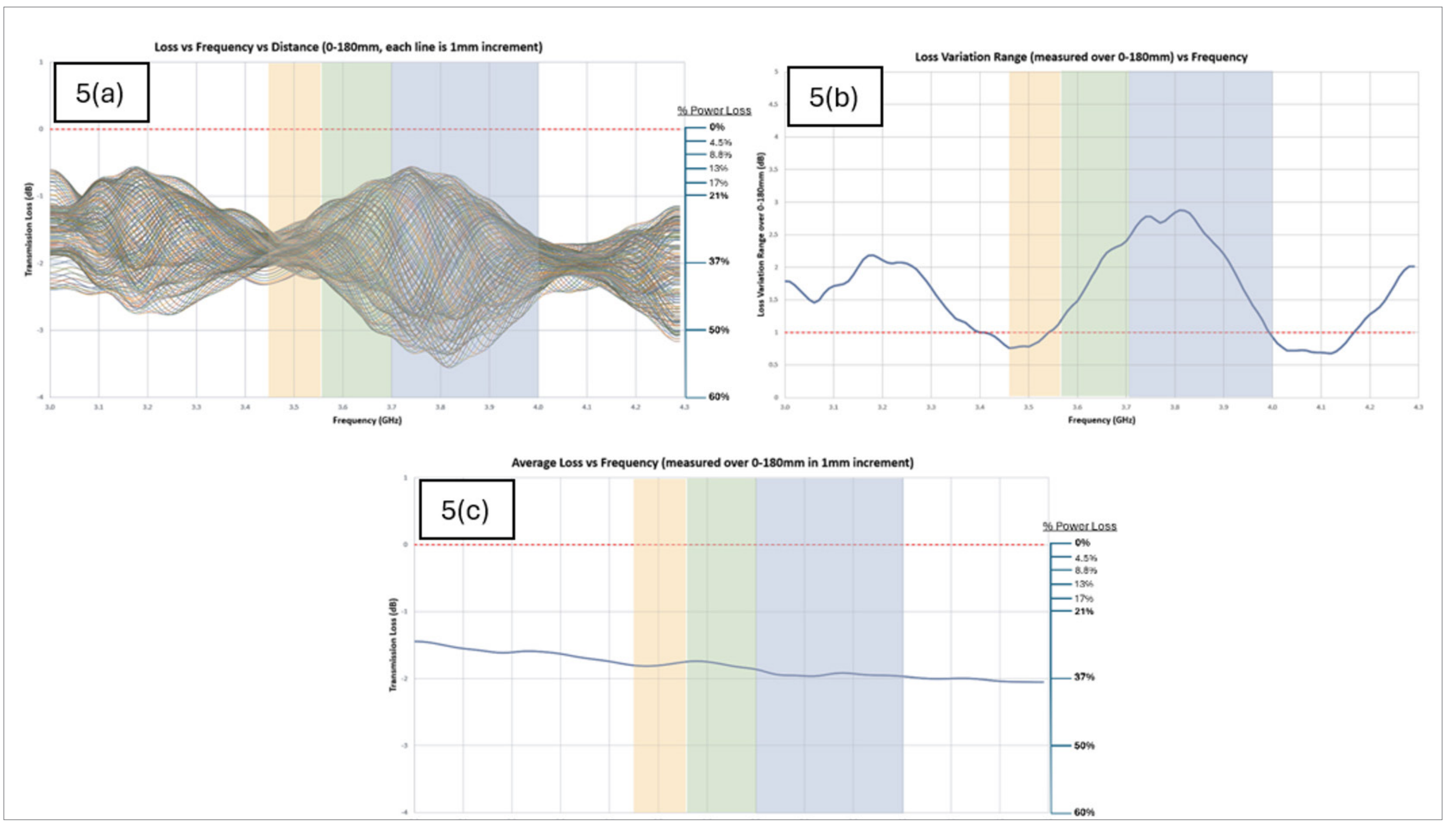

Figure 5: C-band testing on FRP: (a) loss vs. distance vs. frequency, (b) loss variation, (c) average loss vs. frequency. Note: dB is a ratio of power A relative to power B using a logarithmic scale. Alternatively, dB is shown in terms of % Power Loss (reduction of the incident power), provided on the right side of the applicable graphs.

FRP: Figure 5's cyclone plot for ¼-inch FRP showed substantial variation in transmission loss between 3.6 and 4.0 GHz—up to 2.8 dB—depending on placement. The average far-field loss ranged from -1.5 to -2 dB, with measurable degradation in performance.

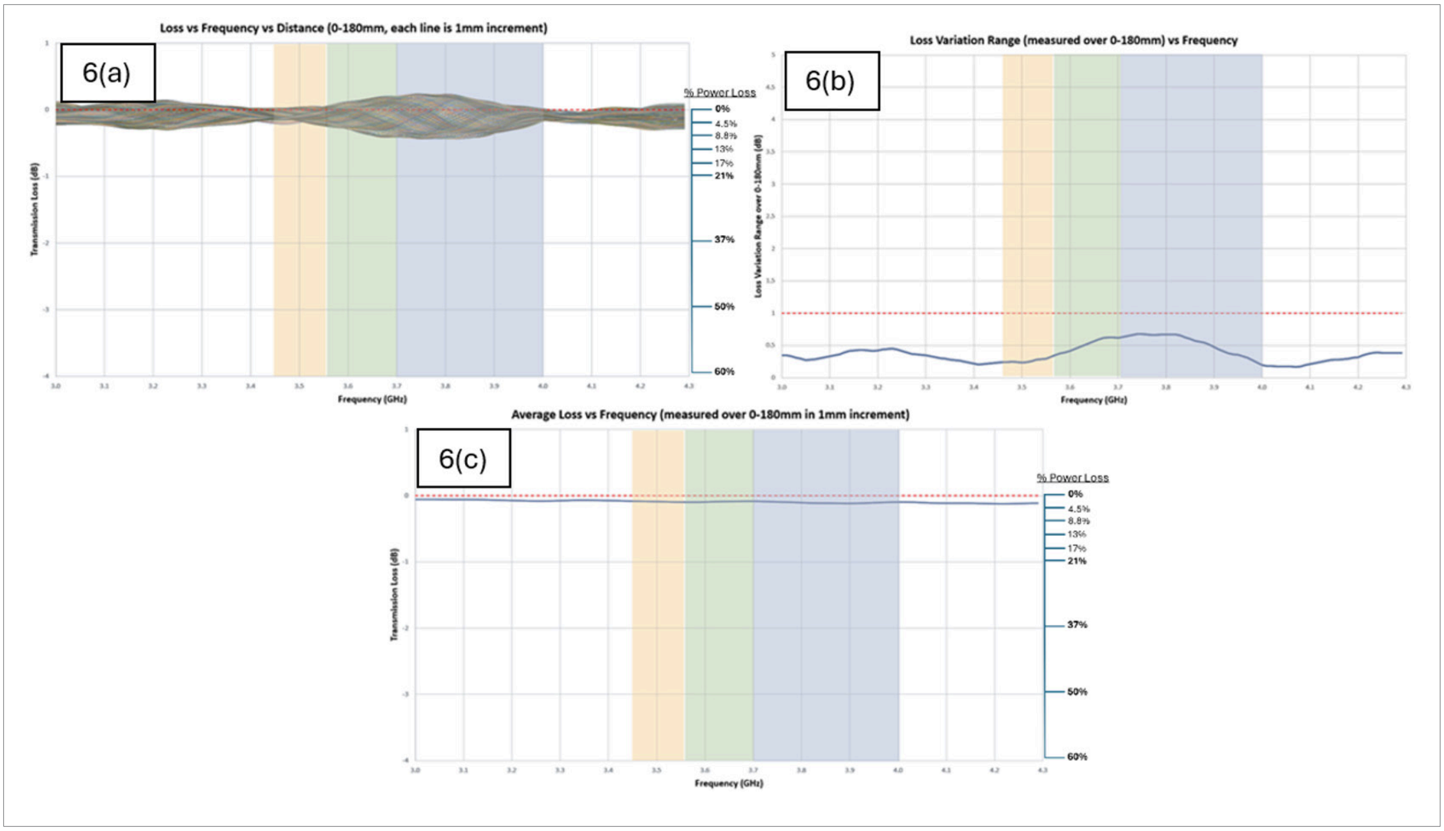

Figure 6: C-band testing on CW S240: (a) loss vs. distance vs. frequency, (b) loss variation, (c) average loss vs. frequency.

clearWave S240: In contrast, clearWave S240 had average loss near -0.1 dB with variation under 0.6 dB. Some measurements showed positive gain due to lensing effects. These results are well within industry guidelines and suggest minimal interference with antenna output.

Low to Mid-Band Results (700 MHz – 2.7 GHz)

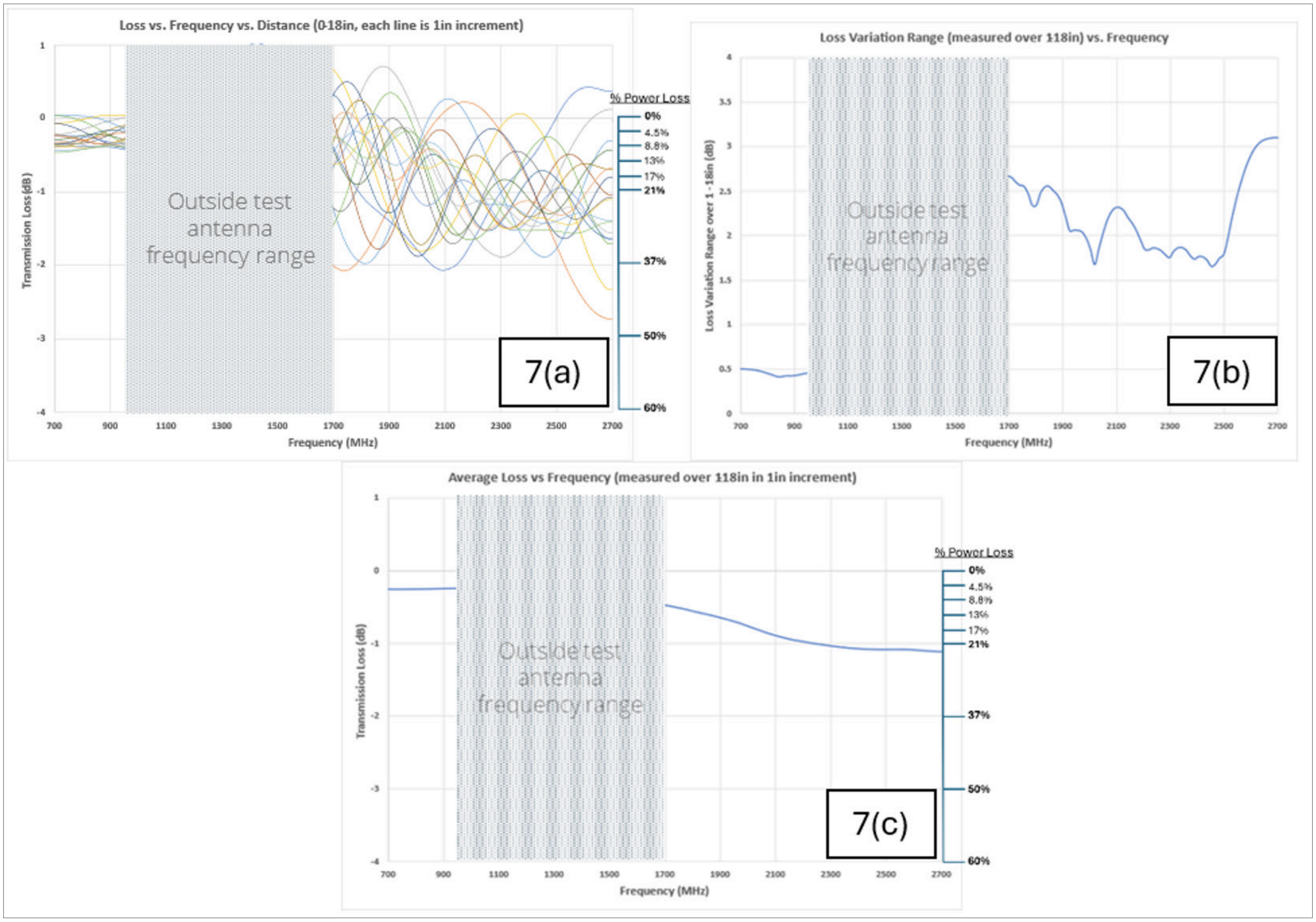

Figure 7: Low-band testing on FRP: (a) loss vs. distance vs. frequency, (b) loss variation, (c) average loss vs. frequency.

FRP: At 700 to 950 MHz, FRP performed acceptably with ~0.3 dB loss. However, between 1.7 and 2.7 GHz, loss increased to 1.0 dB on average, with variation up to 3.0 dB. Some measurements showed positive gain as a result of lensing effects and edge diffraction due to small sample size.

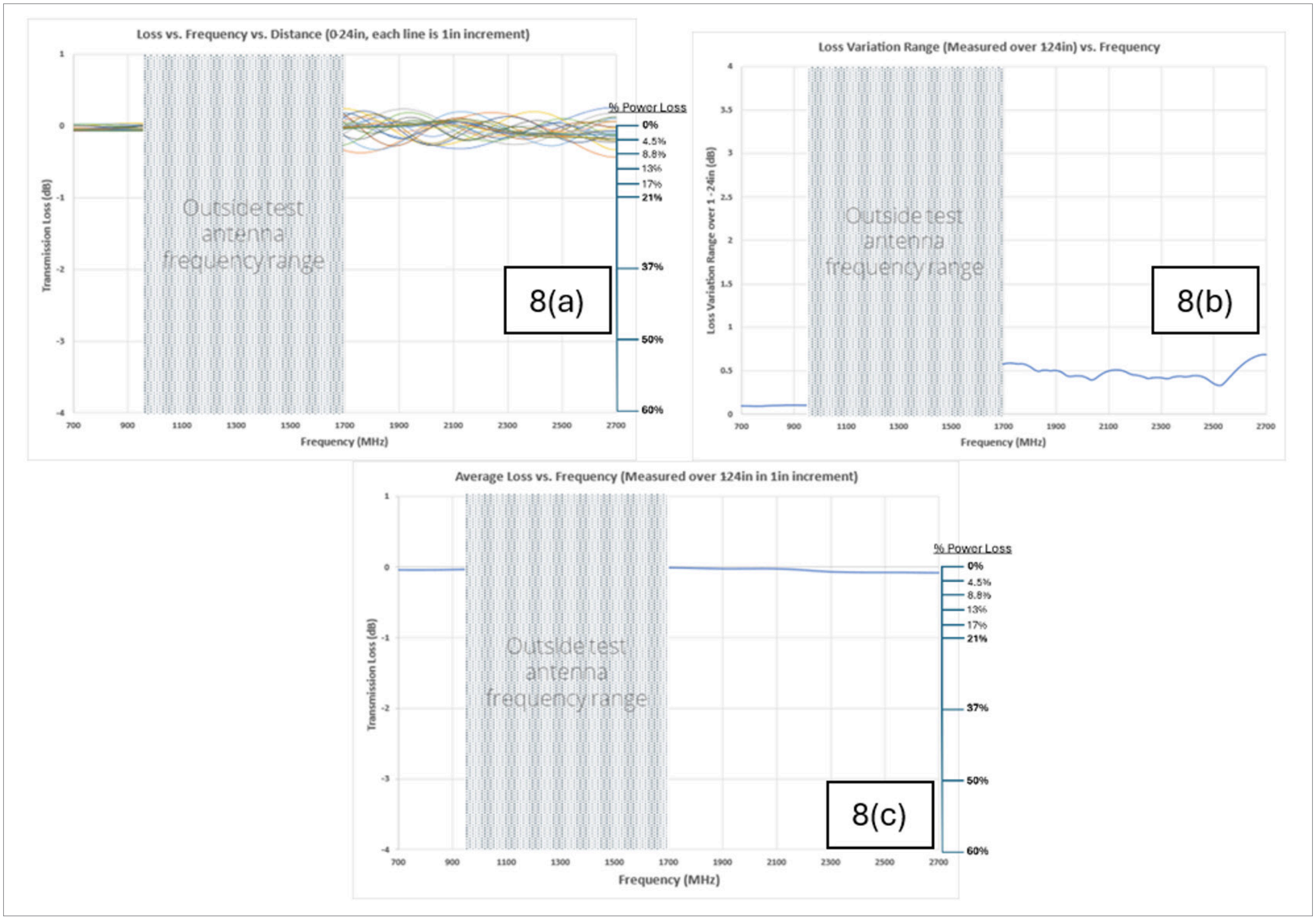

Figure 8: Low-band testing on CW S240: (a) loss vs. distance vs. frequency, (b) loss variation, (c) average loss vs. frequency.

clearWave S240: The same thickness of clearWave S240 maintained losses under 0.1 dB and variation under 0.7 dB, proving far more stable across the mid-band spectrum.

RF Material Selection Matrix

Valmont Telecom's RF Material Selection Matrix compiles data from extensive testing on materials of varying thicknesses, coatings, and frequency ranges (1–40 GHz). Table 1 provides a sample of how FRP, thermoplastics, and other materials perform across sub-6 GHz and mmWave bands.

FREQUENCY				Thermoplastic A				FRP		ClearWave				Plastic B
Name	Band #	Category	Frequency (MHz)	1.57 mm	3.18 mm	4.75 mm	6.35 mm	3.18 mm	6.35 mm	3.0 mm	3.3 mm	4.06 mm	6.1 mm	3.18 mm
700	12	Low Band	699-746	1	1	1	1	1	2	1	1	1	1	1
700	17	Low Band	704-746	1	1	1	1	1	2	1	1	1	1	1
700	13	Low Band	746-787	1	1	1	1	1	2	1	1	1	1	1
700	14	Low Band	758-798	1	1	1	1	1	2	1	1	1	1	1
850	5	Low Band	825-894	1	1	1	1	1	2	1	1	1	1	1
AWS	66 (a)	Mid Band	1710-1780, 2110-2180	1	1	3	4	4	5	1	1	1	1	1
PCS	2	Mid Band	1850-1910	1	1	2	3	3	4	1	1	1	1	1
PCS	25	Mid Band	1930-1990	1	1	3	3	3	4	1	1	1	1	1
2.5G	40, 41	Mid Band	2305-2360, 2495-2690	1	1	2	4	4	5	1	1	1	1	1
CBRS	48	CBRS	3550-3700	1	3	4	4	4	5	1	1	1	1	2
C-Band	77	Mid Band	3700-3980	1	3	4	4	4	5	1	1	1	1	2
LAA	46	LAA	5150-5925	1	4	4	5	5	5	1	1	1	3	3
mmW	261/257	mmW	27500-28350 (28GHz)	5	1	5	1	4	5	3	3	3	4	1
mmW	260	mmW	37000-40000 (39GHz)	4	5	3	4	5	5	2	3	4	1	4

Grading Criteria

Score	Description
1	Best
2	Better
3	Good
4	Poor
5	Bad

Table 1: RF Material Selection Matrix: RF transmission performance of various materials vs. operating frequency.

Table 1 shows the relative RF performance of a few materials at different thicknesses (organized by column) versus frequency (organized by row). Based on the loss and loss-variation from the cyclone plots, the materials were rated using a color-coding scheme and community-accepted values. In low-band, all four materials presented show good performance, although 6.35 mm FRP was given a slightly poorer rating (albeit still acceptable). As frequency is increased to mid-band (moving down the table), materials begin to lose performance. FRP and "thermoplastic A" have poorer ratings on transmission-loss. clearWave and "thermoplastic B," a high-strength thermoplastic, show much better performance.

As frequency is increased even further, materials become "electrically thick," such that the materials' thickness is comparable to the wavelength involved. Here, the loss is sensitive (sinusoidally) to the material thickness. The optimal thickness in this regime is a "half-wavelength" (or integer multiples thereof) which depends on the dielectric constant of the material. A clear example of this is Thermoplastic A around 28 GHz—the 1.6 mm thick panel shows poor transmission, but as thickness is increased to a half-wavelength, the transmission improves since the thickness is better tuned for that frequency. As thickness is increased further, the transmission alternates between high and low—contrary to the popular misconception that "loss always increases with increasing frequency."

CBRS Antenna Patterns

As a final step to understanding the impact of concealments on RF waves, far-field antenna patterns may be measured on the final assembly utilizing the material. In the case for CBRS, ConcealFab has used a 3.6 GHz 40 deg beamwidth antenna spaced 0 and 25 mm away from the material. Both flat and curved materials may be tested. Figure 9 shows a comparison of antenna patterns collected for FRP (Fig. 9a) and clearWave S240 (Fig. 9b) panels. The blue curves represent the baseline measurement of the antenna and frame (no concealment present). The red curve represents the pattern when the concealment is installed in front of the antenna.

In the case of clearWave (Fig. 9b), there is minor impact to the antenna pattern. When swapped out with FRP (Fig. 9a), the gain of the main lobe decreases by almost 3 dB, and the half-power beamwidth decreases by roughly 5-6 degrees. This will lead to decreased antenna range and less cell coverage if deployed in the field. Another noticeable detail in the antenna pattern is increased backlobe power, due to higher reflected power from FRP.

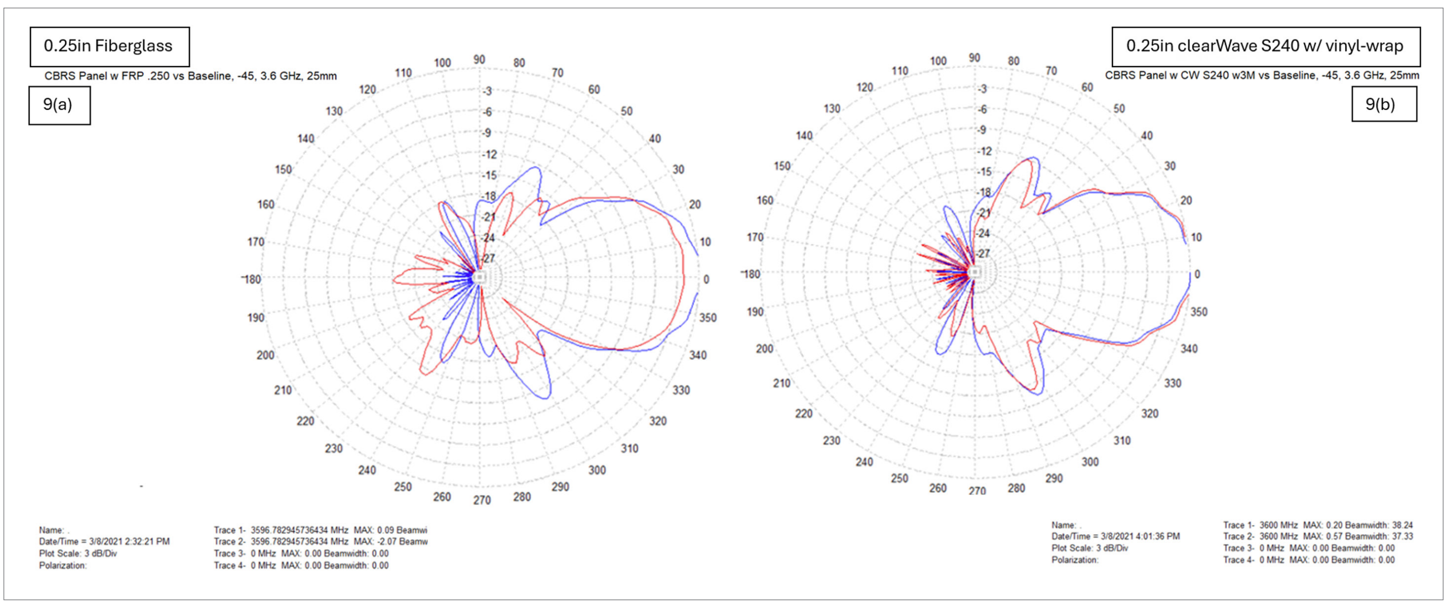

Figure 9: CBRS Antenna Patterns for flat panels of (a) FRP and (b) clearWave S240, spaced 25 mm from the face of the antenna. The blue curve represents the baseline measurement. The red curve represents the concealment.

If deployed, this will redirect unwanted RF energy to any external passive intermodulation (PIM) sources that may be located behind the antenna. If external PIM is actually of concern at the site, depending on the setup of radios and transmit carriers, then the power of intermodulation products falling in the uplink of the antenna will increase. While FRP doesn't generate PIM products in and of itself, it redirects energy to PIM sources leading to greater service disruption.

Conclusion

Our testing demonstrates that traditional materials like FRP, though once considered RF-transparent, may significantly hinder performance at mid-band frequencies when deployed in the near-field of an antenna. With wireless networks increasingly relying on the low- and mid-band spectrum for wide-area coverage, material selection for concealments is critical.

clearWave S240 in Valmont Telecom's ConcealFab products offer consistent, low-loss transmission even in complex real-world scenarios. By reducing reflection and maximizing transmission, mobile operators can extend coverage, minimize interference, and optimize site performance—all while satisfying visual aesthetic requirements.

Looking ahead, Valmont Telecom is expanding its testing framework to new frequencies anticipated in 6G, including non-terrestrial networks and quantum communications. We remain committed to ensuring our concealment solutions are ready for the next decade of mobile innovation.

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