5G Cellular Electromagnetic Window Considerations

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Background

Every pole mounted cellular antenna uses a RF transparent electromagnetic window to protect the antenna from the environment. For 5G and the migration to much higher cellular frequencies and extremely broadband signals, many materials used at current frequencies cannot provide adequate low loss and broad bandwidth performance. This article discusses some issues and tradeoffs.

What 5G is all about

Worldwide, engineers are researching technologies for 5G, the next generation of mobile cellular telephone networks. The “G” in 5G stands for “generation.” 1G wireless cell telephone technology started in the early 1990s and rapidly expanded as companies first started enabling people to send text data between cellular telephones. Each new cellular network generation is typically assigned new frequencies and wider frequency channel bandwidths than its predecessors.

Because everyone wants high speed internet it is no surprise that every major telecom company is working on 5G. The next generation of cellular will build on the foundation created by 4G to allow people to send texts, make cellular calls, and browse the Internet but at dramatically increased speeds. The greater bandwidth will deliver faster, higher-quality video and multimedia content and enable a single mobile device to simultaneously connect to multiple wireless networks as well [1]. 5G will also increase network expandability up to hundreds of thousands of connections [2]. It is a mobile network that needs to keep up with the proliferation of new devices that need mobile internet connections far beyond just cell telephone and Internet. It is predicted that over tens of billions of new devices will be connected to the Internet by 2020. 5G will result in lower latencies, higher number of supported devices, lower infrastructure deployment costs, higher versatility and scalability, and higher reliability of communications [3]. The mobile generation and approximate transfer data rate and approximate RF channel bandwidth needed are shown below in Table 1.

Table 1. Data Transfer Rate and Approximate RF Channel Bandwidth [4]

NETWORK GENERATION	MAXIMUM DATE TRANSFER RATE	APPROX. MAX. RF BANDWIDTH NEEDED	MODE
1G	2.4 kb/s	30 kHz	Analog
2G	64 kb/s	200 kHz	Digital
3G	5.8 Mb/s	20 MHz	Digital
4G	1 Gb/s	100 MHz	Digital
5G	10 Gb/s	1 GHz	Digital

Because greater bandwidth cannot be supported at the cluttered microwave frequency bands currently used (all below about 6 GHz), it is driving the 5G technology toward higher and higher frequencies into the millimeter wave (MMW) frequency bands [5] encompasses from 30 to 300 GHz (the extremely high-frequency (EHF) band of the International Telecommunication Union band designations.) Recently the FCC unanimously voted to open up nearly 11 GHz of high frequency spectrum unlocking frequencies in the MMW bands for future 5G networks in the 28, 37 and 39 GHz bands as well as the unlicensed 64-71 GHz band [6].

Signal Losses are High at MMW

At the three lower frequency bands above, the MMW atmospheric loss is in the order of -0.15 dB/km while at the proposed upper frequency band the atmospheric attenuation is on the order of -0.5 dB/km, as shown in Figure 1. Even worse than atmospheric attenuation is the large signal losses that occur if there is rain as depicted in Figure 2. For instance, for even a very light rainfall of 5 mm/hr the additional signal loss at the lower MMW frequency bands is on the order of -1.5 dB/km while the loss at the high frequency end of the allocated MMW spectrum will be on the order of -3.0 dB/km.

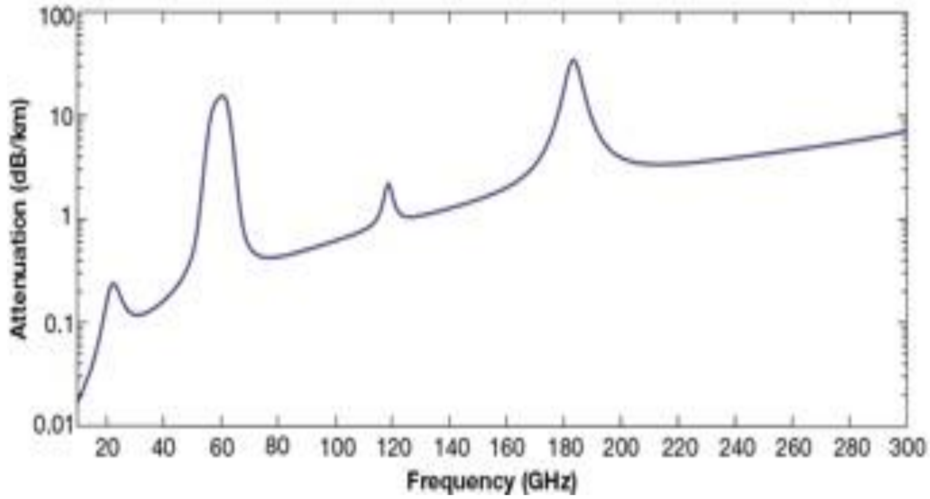

Figure 1. Atmospheric Attenuation at MMW Band [7]

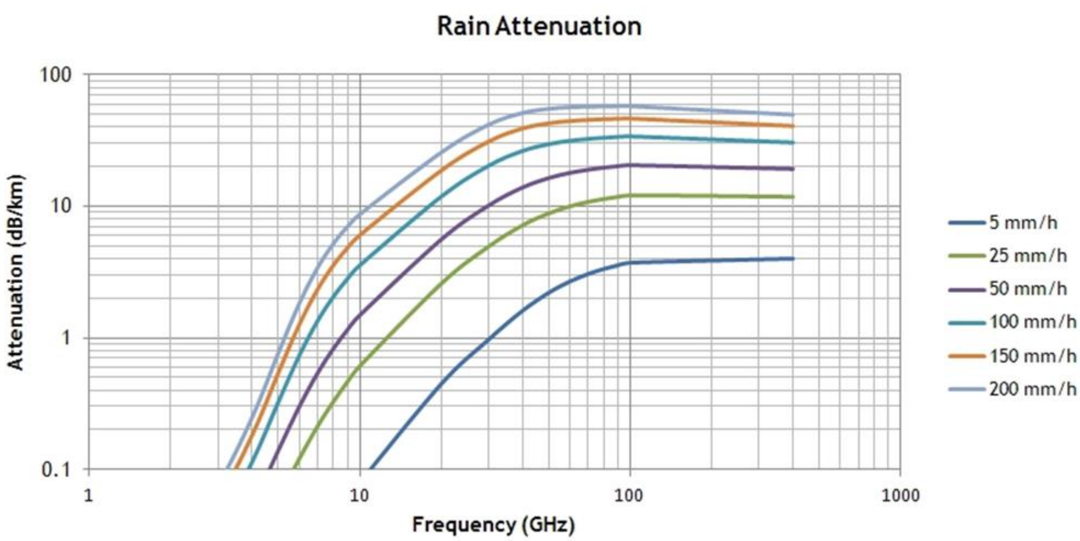

Figure 2. Typical Signal Attenuation in the MMW Due to Rain [8]

In summary, as you move to MMW frequencies atmospheric losses increase, and transmission range gets shorter because of the high attenuation in the signal. For this reason, there is a trend towards use of MMW microcells (a low power cellular base station covering a limited area such as a mall or hotel.) Typically, the communications range of a microcell is less than 2 km whereas the communications range for standard cellular base stations might cover a range up to 35 km [9].

MMW microcells provide very broadband transmission over short ranges and can also be reused across short distances by different network cells using the available spectrum more efficiently. In addition, since antenna size is inversely proportional to frequency, MMW frequencies use smaller antennas allowing one to pack more antennas into devices enabling directional transmissions to steer the signal in a particular direction. More than one antenna operating in the same frequency range can also be used to send multiple data streams adding high network capacity in high density environments. Each microcell operates like a mini cellular tower boosting cellular performance for all users within its range. Densification of small cell outdoor technology increase existing carrier capacity and improves cell edge performance, increasing value of carriers existing spectrum [10].

Figure 3. A Microcell Antenna Mounted on a Pole (Courtesy of Alcatel Lucent)

Choice of Materials for Electromagnetic Windows

The electromagnetic window covering MMW microcell antennas is one place that loss can be reduced by selecting optimum materials. There is a bit of difference in material behavior at MMW frequencies versus lower microwave frequencies, which are currently in use today. For some materials the loss tangent may increase at the MMW frequencies resulting in very large signal losses.

Table 2 lists some candidate materials for consideration for 5G use. Epoxy/fiberglass is the most common electromagnetic window/radome material used at the current lower cellular frequencies (all below about 6 GHz) , The bandwidth and loss requirements for 5G reduce the number of viable candidates.To compare the performance obtainable with the very best UHMWPE tape from DSM, branded as Dyneema®, and the worst case epoxy fiberglass the loss was computed for a full wave thick wall over the MMW frequency range of 66 – 74 GHz and the results plotted in Figure 4. To obtain minimum loss at the center frequency of 70 GHz the Dyneema® thickness for a full wave wall was 0.1136 inches and the epoxy/fiberglass thickness for a full wave wall was 0.0762 inch.

Weight Considerations

Another important factor in the choice of electromagnetic window coverings is the balance of strength and weight. The electromagnetic window (radome) must be strong enough to protect the antenna from wind loads, hail, and other impacts. In comparison to fiberglass/epoxy systems, the potential weight saving by using Dyneema® is significant. A comparison of specific tensile strength, or strength-to-weight ratio, is shown in Figure 5. The weight of new antenna systems is only expected to further increase, since more and more electronics will need to fit in. Hence, significant weight savings by choosing the right radome material will get more and more important. Furthermore, additional savings can be realized due to lower installation and/or permit costs with the lighter weight Dyneema® solutions.

Table 2. Some Candidate Materials for Consideration

MATERIAL	BRAND NAMES	DIELECTRIC CONSTANT	LOSS TANGENT
Epoxy/fiberglass	G10, FR4	4.90	0.0190
Acetal	Delrin, Celon	3.70	0.0050
ABS	Lustran, Cycolac	3.23	0.0200
Nylon 6/6	Zytel	3.20	0.0210
Polyetherimide	Ultem	3.15	0.0013
Polystyrene	Styron	2.75	0.0005
Polycarbonate	Lexan	2.35	0.0100
UHMWPE	Dyneema	2.20	0.0004

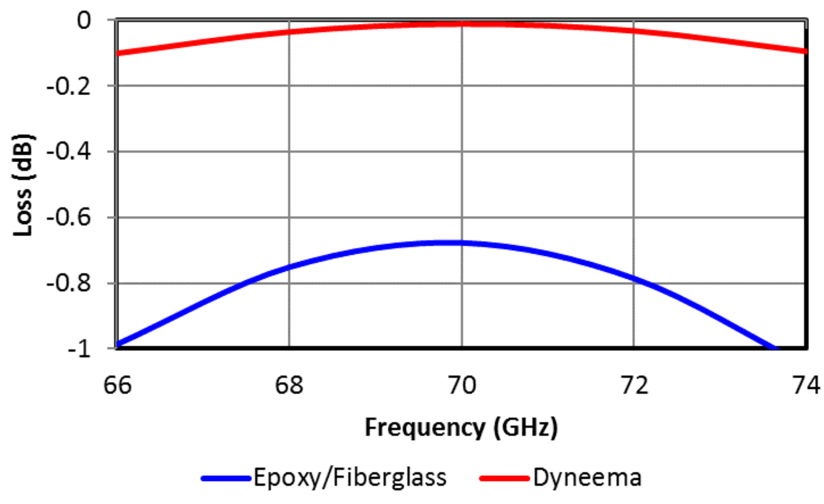

Figure 4. Loss Through a Full Wave of Best and Worst Materials

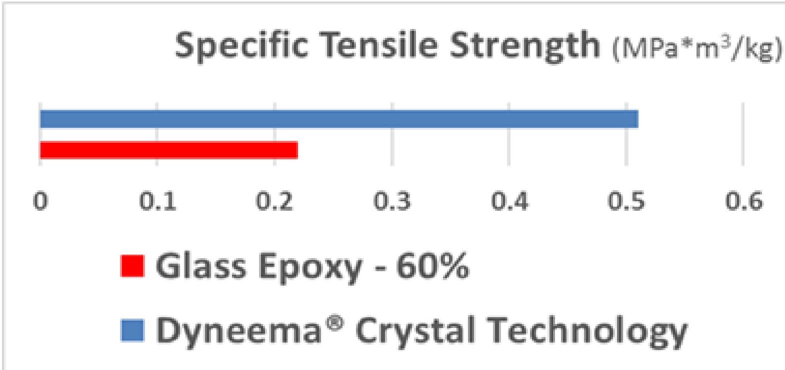

Figure 5. Comparison of Strength-to-Weight Ratio

Conclusions

5G network evolution is driven by the demand for increased throughput capacity to accommodate a vast number of additional wireless devices to be connected to the internet in the future. Small MMW microcells meet this requirement and provide short range service in both indoor and outdoor areas; these can work in either licensed or unlicensed spectrums.

Operation at MMW frequencies is constrained by three factors which restrain microcell performance: (1) increased atmospheric losses due to gaseous absorption, (2) rain attenuation which is dependent on rain rate, and (3) losses through the electromagnetic window covering the MMW microcell antenna. The third factor is dependent on judicious selection of window material since many materials used at the current microwave frequencies (all below 6 GHz) are no longer viable. For instance, epoxy fiberglass, one of the most currently used materials is inadequate; Dyneema® provided the least loss and greatest bandwidth performance of all materials investigated. Additionally, with its light weight and high strength, Dyneema® brings additional advantages beyond excellent EM performance.

References

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