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# THE IMPACT OF MOBILE PHONE COVERS

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# 1 SUMMARY

This report presents the impact protective mobile phone covers of different material have on mobile phone antennas. Two different phones were used for the tests – Phone A with HSPA capability and Phone B with LTE capability.
A plastic, a silicone and a metal cover were tested on Phone A and a cover made of polyurethane plastic on Phone B. For Phone A, TRP and MAC Throughput were measured on standard HSPA. TRP and MAC Throughput were measured on the LTE standard for Phone B. The results showed that due to shielding the metal cover gave considerable lower throughput compared to all the other covers tested. Absorption had an impact when measuring the plastic and silicone covers for Phone A. They proved to cause lower throughput for high frequencies. The polyurethane plastic cover tested on Phone B showed no clear absorption but still difference in throughput. This was probably due to its dielectric properties may have shifted the center frequency of the antenna element.

# 2 INTRODUCTION

It is common nowadays to add a cover to your mobile phone, both for protection and esthetical reasons. They are available in many different stores including the mobile operator branded stores. The material and form varies considerably from one cover to another. You can get everything from plastic and rubber covers to silicon or metal. Of course the different materials have pros and cons. Some are more protective, even against the delivery of data. The question that follows is; how does a cover affect the performance of the antenna? To find out Bluetest tested a couple of different covers - plastic, silicone and metal covers on two different phones, in this report called Phone A and Phone B.

# 3 MEASUREMENT SETUP AND PROCEDURE

The measurements were performed with a Bluetest RTS60 Reverberation Test System, see Figure 1. A Rohde & Schwarz CMW500 Communication Tester was used to simulate the base station. The chamber RMS delay spread was tuned to 50ns with a couple of absorbing elements.
The handsets were measured in free space with an absorption free handset holder. In real life also the hand of the holder will impact the performance. That kind of measurements can be done either by using a hand phantom or by measuring with a live person handling the phone. Performance measurements using a live person can be performed in the Bluetest RTS90. That has however not been the scope of this investigation.


a) b)

*Figure 1, Bluetest RTS60 Reverberation Test System exterior/interior*

## 3.1 PHONE A

On Phone A TRP (Total Radiated Power) and MAC (Media Access Control) Throughput measurements were performed with standard HSPA (High Speed Packet Access). The phone was tested at 2100 MHz (UMTS band I) and 850 MHz (UMTS band V) to see the difference in impact between higher and lower frequency.
H-set 3 was used as fixed reference channel with the modulation 16QAM for the MAC Throughput measurement.

The covers tested on Phone A were made of plastic, metal and silicone. They cover the whole handset except the screen and were easily available in a Swedish electronics store. The plastic cover is solid and has a rubber coated surface, see Figure 2 left. The dielectric constant for plastic is between 2.5 and 3.5 [1]. The metal cover is made of brushed metal on the outside and soft silicone on the inside, see Figure 2 middle. The silicone cover can be seen in Figure 2 right.

*Figure 2, Mobile phone covers tested on Phone A*

## 3.2 PHONE B

On Phone B TRP and MAC Throughput measurements were performed on standard LTE (Long Term Evolution). Phone B works in LTE band 3 (1800 MHz) and 7 (2600 MHz). The modulation 16QAM was used during the MAC Throughput measurements.

One cover made of soft thermoplastic polyurethane (TPU) was tested on Phone B, see Figure 3. TPU is a mixture between plastic and silicone.

*Figure 3, Phone B protective cover*

# 4 RESULTS

The results from the antenna performance measurements with different mobile phone covers (“cases”) are presented below. The HSPA MAC Throughput measured on Phone A is presented in Figure 4 and Figure 5, the TRP values are presented in Table 1 and Figure 6.
The difference in power for the same throughput can also be seen as a difference in distance to the base station. The corresponding relative distances for Phone A can be seen in Table 2 and Figure 7.
The LTE MAC Throughput on Phone B is presented in Figure 8 and Figure 9 and the TRP values are presented in Table 3.

## 4.1 PHONE A

Results from the HSPA MAC Throughput measurement on band I (2100 MHz) is shown in Figure 4. One high and one low channel are plotted for each cover. The different colors represent different covers. Circles represent the 2112 MHz channel and triangles the 2168 MHz channel. Observe that the power needed for the same throughput is noticeably higher when the metal cover is used, approximately 15 dB. It is also higher when using the plastic and silicone cover, around 2-3 dB. Note that the higher frequency channel is more affected by the covers than the lower one (the difference between the channels increase).

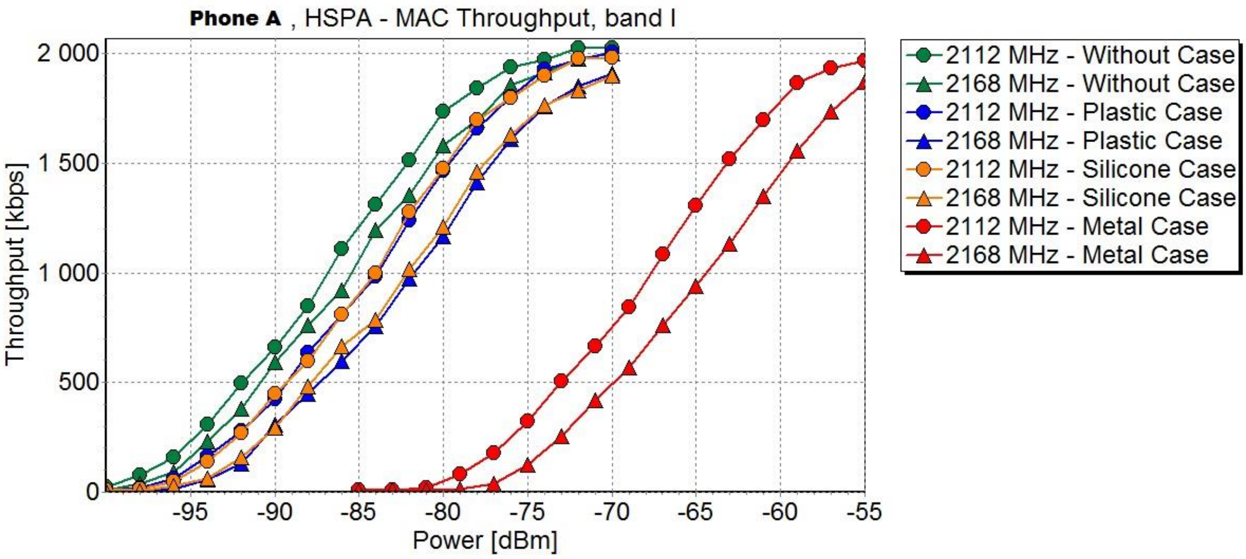


*Figure 4, HSPA – MAC Throughput for Phone A band I*

MAC Throughput on band V can be seen in Figure 5. The different colors represent different covers. Circles represent the 871 MHz channel and triangles the 892 MHz channel. Observe that on this lower frequency band the difference between the channels is small when using the same cover. There is also no significant difference when not using a cover and when using the ones of plastic and silicone. Note that the metal cover still needs a much higher power to get the same throughput. For band I it was approximately a power difference of 15 dB, for this band it is around 10 dB.

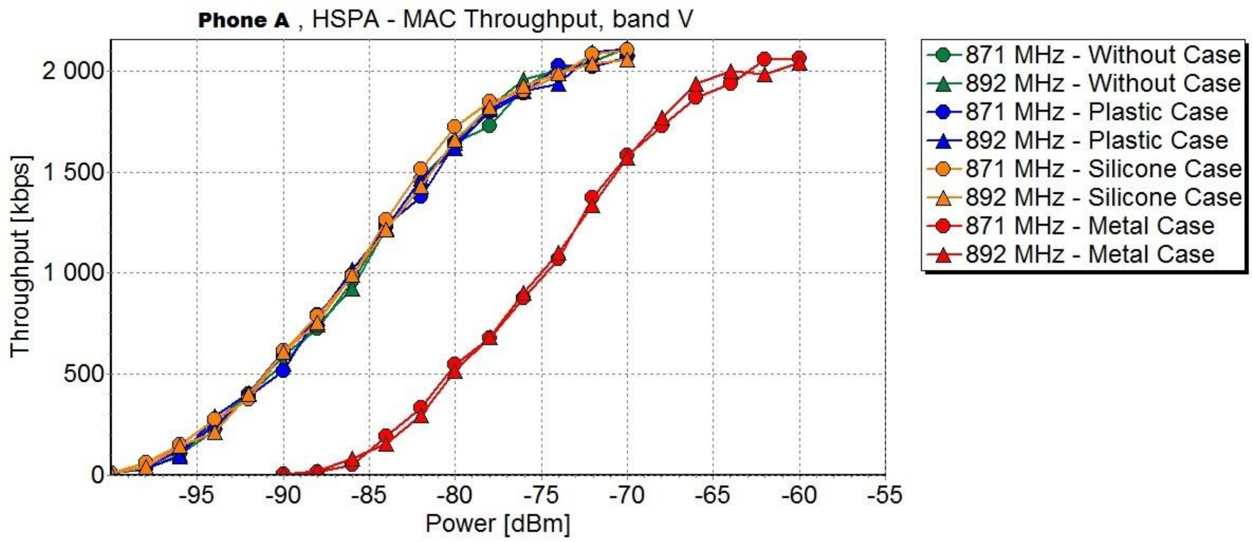


*Figure 5, HSPA – MAC Throughput for Phone A, band V*

The TRP values for the different covers and channels can be seen in Table 1 and Figure 6. Observe that the difference between no cover and the plastic cover is very small. For the lower band the plastic cover measurement gave a higher TRP and for the higher band it gave a lower. As when measuring the throughput, the measurements when using the metal cover differ a lot. For the lower frequency it differs by 15 dB and for the higher 10 dB.

*Table 1, HSPA –TRP for Phone A, band I and V when using different covers*

| HSPA – TRP (dBm) | Band V (Downlink MHz) | | | | Band I (Downlink MHz) | | | |
|---|---|---|---|---|---|---|---|---|
| | 826 | 836 | 847 | Average | 1922 | 1950 | 1978 | Average |
| No Cover | 19.30 | 20.01 | 21.05 | 20.21 | 19.82 | 20.56 | 20.20 | 20.21 |
| Plastic Cover | 20.87 | 21.07 | 21.68 | 21.22 | 19.68 | 20.07 | 20.02 | 19.93 |
| Silicone Cover | 19.98 | 20.87 | 21.32 | 20.76 | 19.76 | 19.86 | 19.74 | 19.79 |
| Metal Cover | 2.969 | 5.822 | 7.646 | 5.88 | 11.10 | 11.91 | 11.73 | 11.59 |

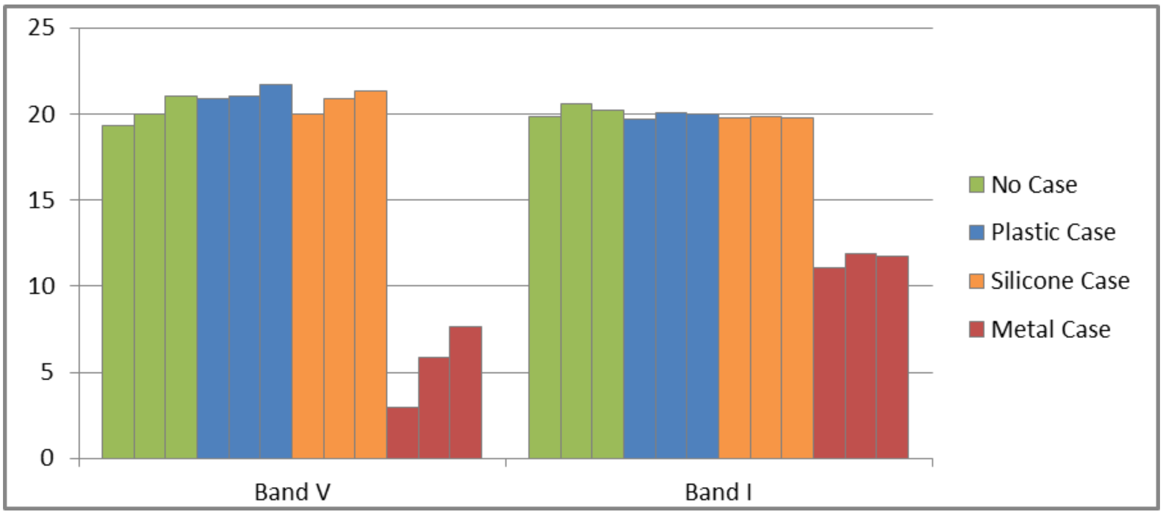


*Figure 6, HSPA –TRP for Phone A, band I and V when using different covers. The bars are from lowest to highest frequency channel.*

### 4.1.1 Real life impact of using a cover

Say that you are standing three kilometers from the base station and you put on your cover, how much closer to the base station would you have to go to get the same throughput? This can easily be calculated assuming the base station is in line of sight, see appendix A.

Summarized in Table 2 is how much closer you would have to be to the base station when using different covers. 100% represents the distance when no cover is used. When using the metal cover we get, as already observed, a much lower throughput. We need to reduce the distance to 10-30 percent to get the same throughput as when not using a cover. So if we are three kilometers from the base station we would have to move more than two kilometers closer to get the same throughput.

Interesting to observe is that for the higher frequency band it is also a considerable difference in distance when using the plastic and silicone cover. You need to reduce the distance to the base station to approximately 70 percent of the original when using those covers. If you are three kilometers from the base station you would have to move almost one kilometer closer to get the same throughput.

*Table 2, Distance to base station when using a cover relative to not using a cover (given the same throughput)*

| Relative distance (%) | Band V (850 MHz) | | | | Band I (2100 MHz) | | | |
|---|---|---|---|---|---|---|---|---|
| | 871 | 881 | 892 | Average | 2112 | 2140 | 2168 | Average |
| Plastic Cover | 100 | 89 | 100 | **96** | 71 | 71 | 63 | **68** |
| Silicone Cover | 100 | 100 | 100 | **100** | 71 | 71 | 63 | **68** |
| Metal Cover | 28 | 28 | 28 | **28** | 11 | 11 | 8 | **10** |

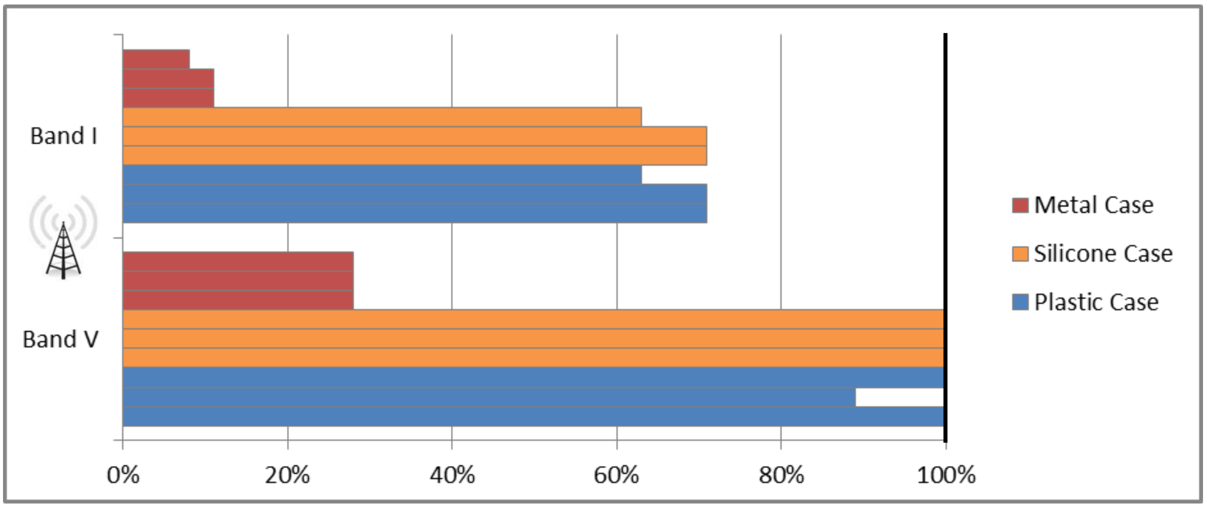


*Figure 7, Relative distance from base station for different covers in order to get the same throughput. 100 percent represent the distance needed without a cover.*

## 4.2 PHONE B

Results from the LTE MAC Throughput measurements on band 3 (1800 MHz) and band 7 (2600 MHz) are shown in Figure 8 and Figure 9. One high and one low channel are plotted with and without a polyurethane plastic cover. The HSPA throughput measurements on Phone A didn't differ noticeable when measuring on the lower frequency band. For the higher band they clearly showed a decrease in throughput when using a plastic cover. This is not the cover here.

When measuring on band 3 (1800 MHz) the throughput is higher when using a cover for both channels, see figure 6. Observe that the difference between using a cover and not is bigger for the lower frequency channel. There, the power needed for the same throughput differs with approximately 1 dB.

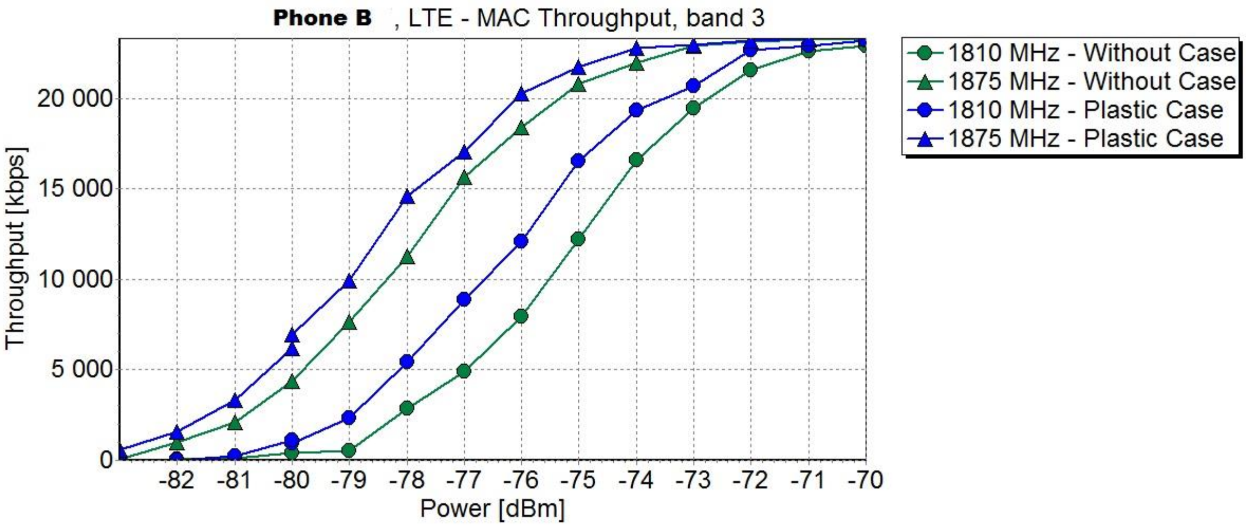


*Figure 8, LTE – MAC Throughput for Phone B on band 3*

For the higher frequency band the difference in throughput between channels was smaller. For the high frequency channel the throughput was approximately the same with and without cover. For the lower channel the throughput was higher without a cover, around 0.5 dB. Observe that in contrast to band 3 the lower channels have higher throughput here.

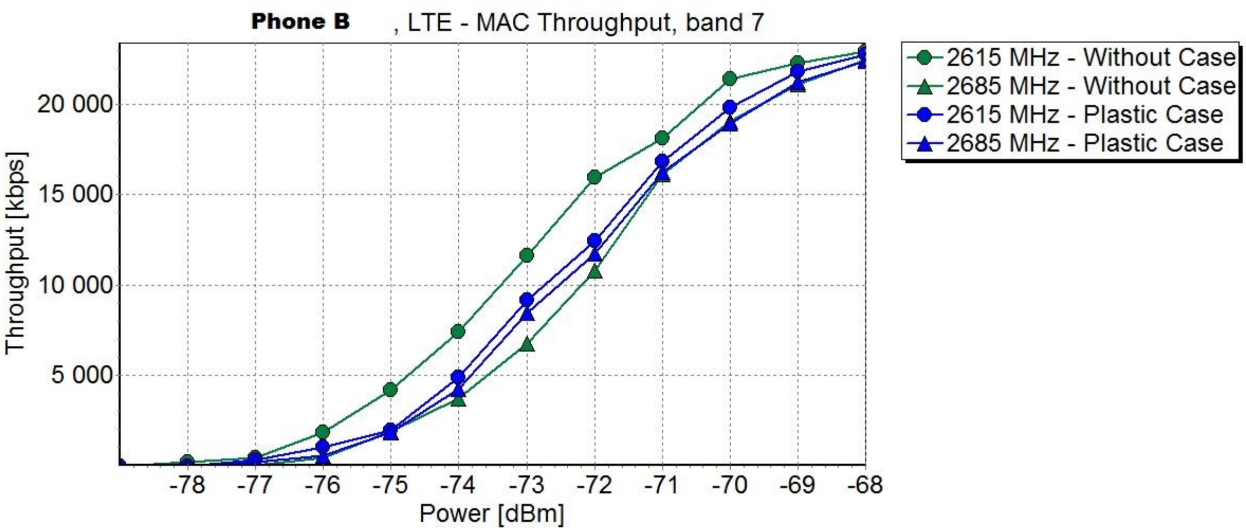


*Figure 9, LTE – MAC Throughput for Phone B band 7*

The TRP values with and without cover can be seen in Table 3. Observe that for the lower frequency band the TRP is approximately 1 dB higher when using a cover. For the higher frequency band on the other hand the TRP is higher when not using a cover, with an approximate difference of 0.5 dB.

*Table 3, LTE –TRP for Phone B band 3 and 7 with and without cover*

| LTE – TRP (dBm) | Band 3 (Downlink MHz) | | | | Band 7 (Downlink MHz) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1715 | 1748 | 1780 | Average | 2505 | 2535 | 2565 | Average |
| No Cover | 17.38 | 17.62 | 20.27 | 18.63 | 18.37 | 17.90 | 18.66 | 18.32 |
| Plastic Cover | 19.38 | 18.96 | 20.84 | 19.80 | 18.30 | 17.66 | 17.99 | 17.99 |

# 5 RESULT ANALYSIS

The results show that mobile phone accessories, like covers, can affect the performance of the antenna. It is most evident when testing the metal cover. You need a 10-15 dB higher power to get the same throughput and the TRP is 10-15 dB lower. The metal in the cover shields the antenna from radiation and prevent delivery of data. It is possible that the metal cover would have affected the throughput even more if the measurements were done with a phantom hand instead of in free space, this due to coupling between the metal and the user's hand.

It can also be seen a noticeable difference in throughput when using a more usual cover made of solid plastic or silicone. For higher frequencies the power needed to get the same throughput increases by approximately 2-3 dB due to absorption in the cover. This means that if you put a plastic or silicone cover on your handset you would need to reduce the distance to the closest base station by almost a third to get the same throughput as before.

What if every customer bought a plastic or silicone cover instead of using the mobile phone without a cover? In order to have as good throughput as when not using a protective cover the distance between two base stations would need to be approximately 1/3 shorter. The area of the base station cells would need to be reduced to $(2/3)^2=4/9=0.44$, i.e. 44% of the original area. This means that the number of base stations would have to increase by 9/4=2.25, i.e. more than the double!

The dielectric constant of the cover's material also affects the throughput. It is possible that a protective cover loads the antenna and changes the center frequency lower. The higher the dielectric constant is the more is the frequency shifted [1]. This could explain the measurements on Phone B using the cover made of polyurethane plastic. Since the difference in throughput between channels is noticeable for both bands, it would seem that it has a clear dependence of frequency within the band. If the center frequency is shifted it would thereby affect the throughput of the channels and it is hard to say if the throughput of the channel increases or decreases if it still is within the band. Another possibility could be that the higher frequency channel actually is shifted to another band just above, whereas the throughput would still be high.

# 6 UNCERTAINTY ANALYSIS

The most important uncertainty factors in these measurements are those that affect the comparison between measurements. One thing that has been changing between the measurements is how charged the batteries of the handsets were. Another thing could be how long time the instruments had been turned on. It is possible that they behave differently depending on how heated they are.

The measurements were done in free space since it was a simple first step and the results were easy to compare. A setup that would be closer to the reality is with a head and hand phantom which is the next step to test. When comparing the different covers it is important that the position of the hand does not change between measurements since that has a great effect of the throughput. This can be verified with Bluetest RTS90 reverberation chamber which is big enough for a person to be in. With this chamber a scenario even closer to the reality can be tested.

# 7 CONCLUSIONS

Based on the results it can be concluded that mobile phone covers do affect the performance of the antenna. How much impact they have can easily be measured with the Bluetest Reverberation Test System. There's a significant difference between using a plastic and metal cover. Metal shields the antenna and the throughput gets lower. For high frequencies 15 dB more power was needed when using the metal cover in order to get the same throughput as without cover.

When measuring a normal plastic and silicon cover they affected the throughput for the high frequencies, approximately 2-3 dB more power was needed to get the same throughput. This is a considerable amount when put into perspective. If every user bought one of these covers and the operator promises the same throughput as when not using a cover, the number of base stations would have to be doubled.

The results from measuring with a TPU cover indicate that those absorb less radiation than normal plastic or silicone covers. A high dielectric constant though, results in a shifting of the center frequency of the band. As long as the channels stay within the band this type of cover does not affect the throughput considerable. With a Bluetest reverberation chamber it can be measured and made sure of.

# REFERENCES

[1] C. Rowell, E. Y. Lam, "Mobile-Phone Antenna Design", *IEEE Antennas and Propagation Magazine,* **54**, 4, August 2012, pp. 14-34.

# APPENDIX

## A FREE SPACE PATH LOSS

Let us say that the base station is in line of sight and transmit the power $P_t$ (dBm) at a distance *d* from the mobile phone that receives the power $P_r$ (dBm). At the frequency *f* the Free Space Path Loss (FSPL) is given by:

$$P_t - P_r = FSPL_{dB} = 20\log f_{MHz} + 20\log d_{km} + antenna\ constants.$$

The difference between received powers gives us the relative distance according to:

$$P_{r1} - P_{r2} = FSPL_2 - FSPL_1 + P_t - P_t = 20\log f - 20\log f + 20\log d_2 - 20\log d_1 = 20\log\frac{d_2}{d_1}$$

$$\Rightarrow \frac{d_2}{d_1} = 10^{\frac{P_{r1}-P_{r2}}{20}}.$$