An Coimisiún um
Rialáil Cumarsáide
Commission for
Communications Regulation

Mobile Handset Performance (Voice) & The Effect of Building Materials on Indoor Mobile Performance

Information Notice

Reference: ComReg 18/78

Version: Final

Date: 30/08/2017

An Coimisiún um Rialáil Cumarsáide
Commission for Communications Regulation
1 Lárcheantar na nDugaí, Sráid na nGildeanna, BÁC 1, Éire, D01 E4X0.
One Dockland Central, Guild Street, Dublin 1, Ireland, D01 E4X0.
Teil | Tel +353 1 804 9600 Suíomh | Web www.comreg.ie

1. ComReg, as part of its programme of work, as set out in its proposed Strategy (ComReg Document 18/74), observed that there may be various potential factors contributing to the public perception that the mobile retail consumer experience has deteriorated such as the increased use of mobile phones with poorer antenna sensitivity performance and changing consumer habits and expectations[1]. As part of the process to seek solutions to deliver improved outcomes and support the Government's Mobile Phone and Broadband Taskforce[2], ComReg published a technical report[3] with the measurement results of the transmit performance[4] of 71 mobile handsets for voice calls which were available in the Irish market as of June 2017.

2. The transmit performance for voice calls of a particular mobile handset is one of a number of factors that may affect the actual quality of the mobile service that a user will experience at any given location. Other factors include:

   - Terrain such as mountains, hills, valleys and foliage;
   - The density of the mobile network (i.e. the number of base stations and the user's distance from the connecting base station);
   - The spectrum bands being utilised by different technologies (2G (GSM), 3G (UMTS), 4G (LTE), etc) and the propagation characteristics of those bands (i.e. the ability of the transmitted radio waves to travel over distance and to penetrate buildings and other physical obstacles);
   - The distance between the user and the base station they are connected to;
   - The effect of building materials on indoor coverage[5];
   - The number of people using mobile handsets at the same time and location.

3. Focusing on voice coverage in the GSM 900 band, and averaging out any variation in Total Radiated Power (TRP) measurements between handset in right hand held to right ear ("BHHR") and handset in left hand held to left ear ("BHHL") usage scenarios, the TRP measurements obtained by ComReg indicate that:

   - The mobile handsets with better transmit performance (higher TRP measurements) included models of feature phones[6] and smartphones. This

[1] https://www.comreg.ie/publication/proposed-strategy-for-managing-the-radio-spectrum-2019-2021/
[2] https://drcd.gov.ie/wp-content/uploads/taskforce-report-final-pdf-1.pdf
[3] https://www.comreg.ie/?dlm_download=mobile-handset-performance-voice
[4] The ability to generate radio waves
[5] https://www.comreg.ie/publication/the-effect-of-building-materials-on-indoor-mobile-performance/
[6] The term "feature phones" in this context refers to those low-cost mobile handsets designed solely for voice calling and SMS/text messaging.

suggests that the often held view that feature phones have better transmit performance than smartphones is not altogether correct as the transmit performance of some models of smartphone compares well against that of some models of feature phone. However, the transmit performance of the tested feature phones was generally good and in most cases it met or exceeded minimum transmit performance standards set by GSM Association[7];

- The mobile handsets with poorest transmit performance (i.e. lowest TRP measurements) were solely smartphones. As well as having overall poor TRP figures, these same handsets tended to exhibit greater variation in transmit performance between BHHL and BHHR usage scenarios compared to feature phones.

4. In fringe coverage areas i.e. where the coverage is poor and the user is far away from the nearest base station, handsets with better TRP values can make the difference in maintaining a voice connection and not.

[7] Table 1, https://www.comreg.ie/?dlm_download=mobile-handset-performance-voice. The GSM Association (commonly referred to as 'the GSMA') is a trade body that represents the interests of mobile network operators worldwide. See http://www.gsma.com/

Summary of Mobile Handset Performance (Voice) Report

5. All measurements were taken in a controlled radio frequency environment and in accordance with the methodologies set by the Cellular Telephone Industries Association. Measurements were done using GSM and UMTS technologies only.

6. The TRP of each mobile handset was measured using two scenarios which simulated the manner in which people typically use their mobile handsets in everyday life – i.e. when making voice calls[8]. TRP measurements were taken for each of these two scenarios:

   - Handset in right hand held to right ear ("BHHR");
   - Handset in left hand held to left ear ("BHHL").

7. Handset transmit performance is determined by measuring the total power radiated by an antenna over a three-dimensional sphere when connected to a transmitter – this is referred to as the **Total Radiated Power** or "**TRP**"[9]. The higher the TRP measurement, the stronger the uplink[10] connection between the mobile handset and the mobile network. And the stronger the uplink connection, the better the experience of the user should be in the quality of mobile voice calls.

[8] Some handsets have an antenna selection feature that enables the handset to automatically select which antenna to use at any time. In order to ensure that all handsets were tested on an equal basis, identical test procedures were used for handsets both with and without antenna selection. It should be noted that in order to test handsets with an antenna selection feature, a specially modified test handset is required and such a modified handset is not commercially available.

[9] https://api.ctia.org/docs/default-source/certification/ctia-test-plan-for-wireless-device-over-the-air-performance-ver-3-6-2.pdf

[10] A mobile handset must connect to the nearest base station in order to access a mobile network. The connection from handset to base station is the "uplink" (handset transmits / base station receives).

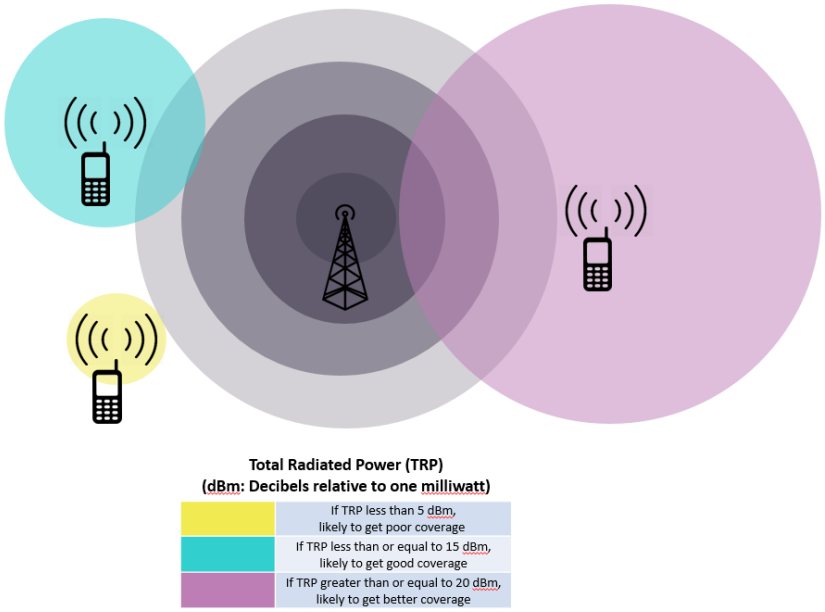

Figure 1 Total Radiated Power (handset in centre and base station between outer circles)

8. Decibels (dB) is a ratio which describes change in signal strength[11]. dBm is an abbreviation for signal power relative to one milliwatt.

Decibels	Change in signal factor
0 dB	= x 1
3 dB	= x 2
6 dB	= x 4
10 dB	= x 10
20 dB	= x 100

Figure 2 Decibels and Signal Factor

9. Mobile network operators use a mixture of coverage and capacity bands to provide service to consumers. The reliance upon multiple spectrum bands means that mobile handsets must contain multiple antennas that are capable of effectively transmitting and receiving signals in those same bands.

10. Mobile handsets must contain multiple antennas, with each antenna designed to transmit and receive radio signals in a specific spectrum band and the antennas must also be of a certain physical size in order to operate effectively. A smartphone's multiple antennas, which are essential components, must compete with all other system components for the amount of available space within the casing.

[11] The dB may be used to express the ratio of two field quantities, such as voltage, current, sound pressure, electric field, charge velocity or density, the square of which in linear systems is proportional to power. Rec. ITU-R V.574 (An. 1), https://www.itu.int/en/ITU-R/Pages/default.aspx

Summary of Building Materials Testing Report[5]

11. Some modern building materials – especially those containing metals such as foil-backed thermal insulation or windows with aluminium or metallic frames - can have a significant impact on radio signals as they penetrate a building. The foil or metal layers help reduce heat loss from inside, but also act to 'reflect' incoming radio signals from outside, effectively shielding the inside of the building from mobile signals outside.

12. ComReg obtained a range of brick, roof tile, window and insulating materials used in contemporary Irish building construction. A dedicated laboratory test environment has been constructed which allows radio signal attenuation through a sample of each of these materials to be measured over the frequency range in which mobile signals operate in Ireland. The resulting attenuation measurements allow an assessment of the range of attenuations caused by different building materials to be made.

13. Windows: For all **window materials** tested there was between 15 and 45 dB additional power loss compared to the reference loss. Losses tended to increase with frequency.

14. Insulating Materials: Across all **insulation materials** tested, there was between 15 and 60 dB additional power loss compared to the reference loss. Again, losses tended to increase with frequency.

15. Block Materials: The **block** materials tested predominantly exhibited 5 dB of attenuation compared to the reference result, with the exception of **cavity blocks**, which caused an additional 25 dB of attenuation compared to free space.

16. Roof Materials: Concrete roof tiles attenuated the most of the **roofing materials** tested, with roughly 5 dB of attenuation at higher frequencies compared to the reference result. Overall, **roofing materials had only a small effect on radio propagation**.

17. In summary, the building materials which caused the most radio attenuation were those used in heat insulation (especially those with one or more foil layers) and windows (especially triple-glazed windows with aluminium or PVC frames). Roofing materials tested did not contribute significantly to radio attenuation, while of the brick materials tested only Cavity Blocks caused significant attenuation.

18. The report finds that the use of some modern building materials, in particular, those containing metals such as foil-backed thermal insulation or windows with aluminium or metallic frames can have a significant detrimental effect on the propagation of radio waves as they penetrate a building. The losses suffered by radio waves penetrating these materials is in the order of 20 up to 60 dB – that is a reduction in signal strength of 100 up to 1,000,000 times and future ComReg research may, amongst other things, consider how these materials might act in aggregate. ComReg further notes that while many consumers currently receive some level of mobile signal while indoors, this position seems likely to be further exacerbated as building and insulating materials used become even more energy efficient.

What else is ComReg doing?

19. The Mobile Handset Performance (Voice) report is the first in a series of voice and data reports and ComReg expects that the next report will present results for data following similar tests being undertaken to measure data performance on the same 71 mobile handsets.

20. ComReg has put in place a scheme that allows the use of mobile phone repeaters that meet the technical conditions set out by ComReg [12]. A repeater is a device that re-transmits amplified signals it receives[13]. Repeaters offer consumers the ability to amplify the indoor signal.

21. An option currently available from some service providers is 'Native Wi-Fi'. Native Wi-Fi calling is a service for Android and iOS smartphones providing the ability to make and receive phone calls over an internet connection with sufficient download speed and latency in the home. ComReg has previously acknowledged that, eventually and in most instances, native Wi-Fi calling is likely to be the most effective mechanism to improve indoor reception issues. Consumers who have both an internet connection and a Wi-Fi calling enabled phone would be able to avail of Wi-Fi calling. eir is the only Irish mobile network operator (MNO) to have rolled out native Wi-Fi calling on its network and is currently adding additional supported devices to extend the reach of the service[14]. ComReg is actively encouraging all mobile service providers to follow suit and notes that Vodafone plans to launch "*VoWifi*" (Voice over Wi-Fi) during 2018, which it seems will provide a similar service for Vodafone customers[15].

22. A coverage mapping project is underway within ComReg that will, when complete, offer consumers the ability to check mobile phone coverage nationwide.

[12] https://www.comreg.ie/publication/mobile-phone-repeaters-response-to-consultation-and-final-decision/
[13] https://www.comreg.ie/publication/mobile-phone-repeaters-consultation/
[14] See https://www.eir.ie/wificalling/
[15] See https://www.siliconrepublic.com/comms/vodafone-voice-lte-wifi

Appendix 1: Measurement Results

23. The following table sets out the TRP measurements for the BHHR scenario (handset in right hand held to right ear) for all 71 handsets in the GSM 900[16], GSM 1800[17], UMTS 2100[18] and UMTS 900[16] bands. The handsets are listed in decreasing order of TRP measurements in the GSM 900 band. Given that GSM 900 is the lowest frequency band of all the GSM bands and due to its propagation characteristics it provides the best coverage, therefore phones were listed in decreasing order of TRP measurements in the GSM 900 band[19].

[16] The “900 MHz band” means the 880 to 915 MHz band paired with the 925 to 960 MHz band as set out in Annex 3 to ComReg Document 12/25.
[17] The “1800 MHz band” means the 1710 to 1785 MHz band paired with the 1805 to 1880 MHz band as set out in Annex 3 to ComReg Document 12/25.
[18] The “2100 MHz band” means the 1920 to 1980 MHz band paired with the 2110 to 2170 MHz band.
[19] https://www.gsmaintelligence.com/research/?file=c12ea515e04188c7acdbfc35afca6b23&download

Mobile Handset	GSM - 900	GSM - 1800	UMTS - 2100	UMTS - 900
Doro PhoneEasy 631 (F)	23.0	25.5	16.6	13.2
Samsung Galaxy S8+ (S)	22.6	21.8	13.4	12.9
Xiaomi Mi Note 2 (S)	22.5	21.9	14.2	12.4
Sony Xperia XZ (S)	21.7	24.6	18.6	11.2
HTC Desire 825 (S)	21.5	22.2	17.7	12.7
Samsung Galaxy J3 (S)	21.3	21.1	14.1	11.0
Nokia 3310 (F)	21.2	23.2	N/A	N/A
Samsung Galaxy S7 edge (S)	21.0	21.8	14.7	11.6
Alcatel Idol 4 VR Edition (S)	20.9	22.3	15.7	10.6
Nokia 130 (F)	20.9	19.7	N/A	N/A
Doro Liberto 825 (S)	20.7	23.5	15.7	10.9
Samsung Galaxy S5 Mini (S)	20.6	22.7	12.3	10.6
Motorola Moto E (S)	20.6	22.7	16.7	12.6
Alcatel 1016 (F)	20.6	19.9	N/A	N/A
Microsoft 650 (S)	20.4	18.0	16.1	12.2
Vodafone Smart First 7 (S)	20.2	21.2	13.8	11.6
Alcatel Pixi 4 (3G) (S)	20.2	21.1	13.4	11.2
Huawei P9 Lite (S)	20.1	21.6	13.7	10.2
Vodafone Smart ultra 7 (S)	20.0	17.7	13.1	9.8
Alcatel 2045 (F)	19.9	20.2	13.4	11.4
Huawei GX8 (S)	19.9	14.3	14.4	10.1
HTC One M8s (S)	19.8	19.6	13.2	7.6
Sony Xperia M4 (S)	19.8	23.7	18.1	10.6
LG G6 (S)	19.6	22.4	14.3	10.3
Sony Xperia Z3 (S)	19.6	20.5	11.8	12.5
Samsung Galaxy J1 (S)	19.6	20.9	11.3	9.1
Samsung Galaxy A3 (S)	19.5	22.6	11.5	10.2
Microsoft 640 (S)	19.5	21.7	16.2	10.6
Huawei Y5 (S)	19.5	23.4	16.1	9.4
Alcatel Pixi 4 (4G) (S)	19.3	20.6	13.0	10.2
Samsung Galaxy Note 5 (S)	19.2	19.1	12.6	10.4
Samsung Galaxy S8 (S)	19.1	23.6	15.4	9.2
Samsung Galaxy S6 (S)	19.1	22.9	12.9	11.0

Mobile Handset	GSM - 900	GSM - 1800	UMTS - 2100	UMTS - 900
Apple iPhone 6s (S)	18.8	14.7	10.7	10.8
Sony Xperia X (S)	18.8	23.7	17.2	11.3
Samsung Galaxy S7 (S)	18.8	21.6	13.9	10.2
Huawei Honor 8 (S)	18.7	23.9	16.0	8.7
Vodafone Smart Turbo 7 (S)	18.5	21.1	12.7	11.2
Sony Xperia E5 (S)	18.4	20.7	14.8	9.1
Nokia 222 (F)	18.4	18.7	N/A	N/A
Samsung Galaxy J5 (S)	18.4	21.8	13.6	9.4
Microsoft 550 (S)	18.4	21.0	15.6	9.2
Motorola Moto G4 (S)	18.2	21.5	15.7	8.6
Apple iPhone 6s+ (S)	18.1	15.3	8.6	7.5
Google Pixel XL (S)	18.1	18.3	10.6	9.7
Sony Xperia XA (S)	18.1	23.5	13.1	9.0
Motorola Moto E3 (S)	17.9	22.0	12.6	8.2
Huawei Mate S (S)	17.9	21.7	15.9	7.3
Huawei Y3 (S)	17.8	21.1	14.6	7.7
OnePlus 3T (S)	17.7	13.2	7.8	7.0
Huawei Honor 7 (S)	17.7	23.3	16.3	8.7
Google Pixel (S)	17.5	21.0	12.8	8.8
Apple iPhone 5s (S)	17.3	18.3	8.9	7.6
HTC Desire 530 (S)	17.2	23.1	16.6	9.2
Apple iPhone SE (S)	17.2	17.2	6.4	8.3
Xiaomi Mi5s (S)	17.1	16.5	13.2	9.3
HTC One A9 (S)	17.1	20.0	15.1	8.4
Apple iPhone 6 (S)	17.1	17.2	13.5	8.9
Apple iPhone 7 (S)	16.9	16.6	10.3	8.5
HTC 10 (S)	16.9	17.9	12.8	6.7
Huawei Y6 (S)	16.9	21.0	14.8	8.0
Apple iPhone 7+ (S)	16.9	10.9	7.7	8.4
Huawei P10 (S)	16.7	17.1	15.3	6.0
Motorola Moto G (3rd Gen)(S)	16.7	21.2	18.4	10.0
Samsung Galaxy S6 edge (S)	16.5	20.8	13.5	9.1
Microsoft 950 (S)	16.4	20.2	13.3	8.9
Huawei P9 (S)	16.1	20.0	15.7	7.0
Alcatel POP 4 Plus (S)	13.6	23.1	15.4	5.6
Huawei Honor 8 Pro (S)	13.5	19.7	12.2	3.9
Huawei Mate 9 (S)	9.2	17.7	12.1	-2.6
Huawei P10+ (S)	7.8	9.9	12.8	-2.1

Figure 3 TRP (dBm) for the BHHR scenario in the GSM 900 band in decreasing order

***F – Feature Phone, *S – Smart Phone**

24. The following table sets out the TRP measurements for the BHHL scenario (handset in left hand held to left ear) for all 71 handsets in the GSM 900[16], GSM 1800[17], UMTS 2100[18] and UMTS 900[16] bands. The handsets are listed in decreasing order of TRP measurements in the GSM 900 band. Given that GSM 900 is the lowest frequency band of all the GSM bands and due to its propagation characteristics it provides the best coverage, therefore phones were listed in decreasing order of TRP measurements in the GSM 900 band[19].

Mobile Handset	GSM - 900	GSM - 1800	UMTS - 2100	UMTS - 900
Doro PhoneEasy 631 (F)	24.2	26.4	16.8	14.5
Samsung Galaxy S8+ (S)	22.2	24.3	16.9	11.7
Huawei GX8 (S)	22.0	21.2	14.1	9.6
Doro Liberto 825 (S)	21.9	22.9	16.1	11.5
Microsoft 650 (S)	21.6	22.2	11.4	13.0
Motorola Moto G (3rd Gen) (S)	21.5	25.0	19.9	13.3
Alcatel 2045 (F)	21.4	22.8	14.6	13.1
Alcatel 1016 (F)	21.4	19.4	N/A	N/A
Samsung Galaxy S8 (S)	21.2	23.1	16.4	11.0
Sony Xperia XZ (S)	21.1	19.4	12.4	10.9
Vodafone Smart First 7 (S)	20.9	22.3	14.5	11.6
LG G6 (S)	20.8	20.8	13.9	11.3
Nokia 130 (F)	20.8	23.2	N/A	N/A
Samsung Galaxy A3 (S)	20.4	23.8	14.4	11.2
Xiaomi Mi Note 2 (S)	20.3	21.2	14.2	9.5
Samsung Galaxy S7 edge (S)	20.2	20.4	12.9	11.4
Nokia 3310 (F)	19.9	21.9	N/A	N/A
HTC 10 (S)	19.8	17.4	11.7	8.6
Microsoft 640 (S)	19.7	23.8	17.1	11.5
Huawei Mate S (S)	19.7	11.0	3.7	10.9
Motorola Moto E (S)	19.6	18.7	12.9	9.6
Motorola Moto G4 (S)	19.6	21.6	14.7	9.0
Alcatel Idol 4 VR Edition (S)	19.5	23.0	16.1	10.1
Google Pixel XL (S)	19.3	18.9	13.5	10.3
HTC One M8s (S)	19.3	20.9	11.2	7.2
Sony Xperia M4 (S)	19.3	17.9	9.8	10.3
Google Pixel (S)	19.3	21.2	14.6	8.4
Huawei Y3 (S)	19.2	20.1	13.3	7.7
Vodafone Smart Turbo 7 (S)	19.2	22.0	14.4	11.6
Samsung Galaxy Note 5 (S)	19.1	21.8	13.5	9.6

Mobile Handset	GSM - 900	GSM - 1800	UMTS - 2100	UMTS - 900
Samsung Galaxy J3 (S)	19.0	19.6	13.0	8.6
Huawei Honor 8 (S)	19.0	22.2	15.2	10.0
Xiaomi Mi5s (S)	18.7	17.0	10.8	10.2
HTC Desire 825 (S)	18.7	19.7	14.9	10.6
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Huawei P9 Lite (S)	18.7	22.6	16.3	9.1
Nokia 222 (F)	18.6	21.1	N/A	N/A
Huawei Y5 (S)	18.6	22.4	15.1	8.5
Samsung Galaxy J1 (S)	18.3	20.6	12.5	8.6
Sony Xperia XA (S)	18.2	22.5	12.3	9.1
Alcatel Pixi 4 (4G) (S)	18.0	22.1	14.3	9.0
Samsung Galaxy S7 (S)	18.0	20.5	15.5	10.9
Samsung Galaxy J5 (S)	18.0	23.2	13.5	8.7
HTC One A9 (S)	17.9	18.4	13.4	6.4
Samsung Galaxy S5 Mini (S)	17.9	22.8	13.6	7.9
HTC Desire 530 (S)	17.6	19.2	13.2	9.1
Microsoft 950 (S)	17.5	22.5	15.5	11.0
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Huawei Y6 (S)	16.9	22.2	14.3	7.8
Alcatel Pixi 4 (3G)	16.8	20.7	13.3	7.7
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Sony Xperia Z3 (S)	16.7	20.3	11.9	9.0
Sony Xperia E5 (S)	16.5	20.8	14.0	7.6
Huawei P9 (S)	16.5	21.3	14.9	8.4
Sony Xperia X (S)	16.3	20.7	15.6	8.7
Microsoft 550 (S)	16.0	20.7	17.1	10.2
Huawei Mate 9 (S)	15.8	19.5	11.5	7.4
Apple iPhone SE (S)	15.1	20.0	10.8	6.0
Apple iPhone 7 (S)	14.9	21.3	14.9	5.8
Huawei Honor 8 Pro (S)	14.7	11.7	5.9	6.8
Alcatel POP 4 Plus (S)	14.6	19.7	13.9	6.5
Apple iPhone 6 (S)	13.8	21.2	15.9	5.5
Huawei P10+ (S)	13.7	19.6	8.9	5.8
Samsung Galaxy S6 edge (S)	13.2	24.0	16.4	5.1
Apple iPhone 5s (S)	12.2	21.1	14.5	3.3
OnePlus 3T (S)	11.5	20.5	13.6	2.5
Apple iPhone 7+ (S)	8.5	18.9	12.1	-2.1
Apple iPhone 6s (S)	8.2	20.9	10.3	-0.5
Apple iPhone 6s+ (S)	5.1	20.4	14.4	-4.4

Figure 4 TRP (dBm) for the BHHL scenario in the GSM 900 band in decreasing order

***F – Feature Phone, *S – Smart Phone**