Coins as Measure of Size

Gerald Artner, *Member, IEEE*

***Abstract*—Coins are used as a measure of size in scientific publications. Over hundred examples are collected. Although standardized procedures for using coins as measure of size do not exist, use among scientists is so widespread that some form of consensus has formed in the community. Contemporary usage patterns of coins as measure of size are analyzed qualitatively. Several rules and predictions are formulated based on this analysis.**

***Index Terms*—coin, numismatics, dimension, measurement, size.**

I. Introduction

PHOTOGRAPHS are widely used to depict prototypes in scientific publications. To denote the size of an object in a photograph, a variety of methods are common among scientists. Well known objects have been used as comparison to give a rough size estimate in photographs, e.g. pens [1, Fig. 6], hands [2, Fig. 2], playing cards [3], matchboxes [4] and an iPhone 5 [5, Fig. 1]. The placement of these objects in photographs is no accident, e.g. the caption of [5, Fig. 1] clearly states "Millimeter-wave radar for vital signs monitoring prototype (dimensions comparison with iPhone 5)." These size comparisons are often insufficient. The object's size is then determined more precisely by performing measurements. One technique is to measure lengths and add dimensions later with image editing, e.g. [6, Fig. 2]. A common technique is to make the measurement procedure part of the photographs by adding rulers (e.g. [7, Fig. 3]) or objects of defined known size such as cubes with a specified side length (e.g. cubes with a side length of 1 cm [8, Fig. 2] or 5 cm [8, Fig. 11]) and coins.

Most coins are of roughly the same size in the centimeter region. This allows the concept of coins to be used as a rough estimate of size and indeed some authors advertise devices as coin-sized [9]. However, the size of each specific coin is standardized. The use of a specific coin is therefore not only a size reference as in coin-sized; it is a true measure of an objects size. Of course coin sizes can be converted to other well-known measures of size, such as meter or inch; this does not appear to be necessary, as coin sizes are well known to everyone in the community. Note however, that coins are used as a measure of size, but not as a measurement unit (see rule 3).

Contribution — Over hundred scientific publications are collected from the field of electrical engineering which use coins as measure of size. It is shown that this practice is used throughout peer reviewed conferences, letters, magazines and journals; and that it is widespread among publishers and countries. Common practices for coin use are identified. Counterexamples to best practice are referenced if known to the author. The coin measurement technique is developed further by giving counterexamples to those rules, where no counterexample was found in the literature. Several predictions are formulated based on these qualitative investigations.

This is a preliminary version of the manuscript that was published on the authors personal website geraldartner.com. The fully edited version is published as G. Artner, "Coins as Measure of Size," *IEEE Instrumentation and Measurement Magazine*, vol. 23, no. 2, pp. 88-93, 2020.

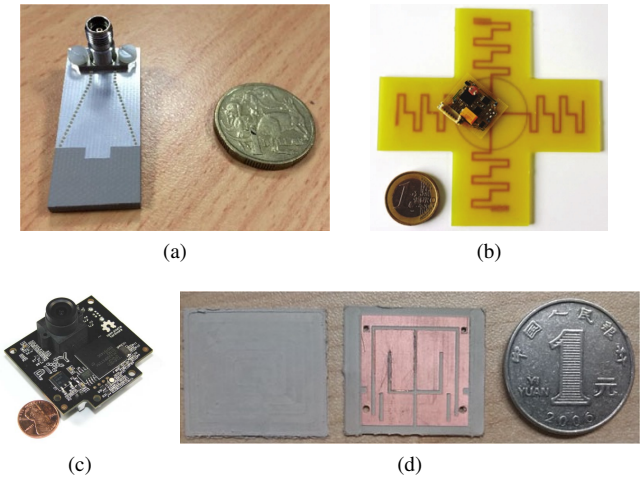
II. Coins Used as Measure of Size in Scientific Publications

Over hundred peer-reviewed scientific publications are investigated for their use of coins as measure of size. It is not the goal of this article to provide a quantitative description or investigate a historical origin. The large number of scientific publications containing photographs, in which coins are used as a measure of size, shows that there is consensus among authors, reviewers and publishers, that coins are an acceptable measure of size.

Samples were found and collected by browsing the literature as part of the author's regular reading and literature research routines. The inclusion criterion is that a coin is used as measure of size in at least one figure in a paper that is published in a peer-reviewed conference, journal, magazine or in a scientific book. Papers were mainly collected from the areas of antennas and propagation and electrical engineering in general as a consequence of the author's research interest. The full list of investigated works with the shown coins and their usage is available on IEEE DataPort [10].

Samples of coins used as measure of size are collected from all publication types in the antennas and propagation community (the number of included works are given in brackets): conferences COMCAS (1), TELFOR (1), APS-URSI (1), EuCAP (53), letters (19), magazines (3), transactions (10) and books (2). They are collected from journals outside antennas and propagation: *IEEE Micro* (1), *IEEE Microwave Magazine* (2), *IEEE Microwave and Wireless Components Letters* (1), *IEEE Transactions on Microwave Theory and Techniques* (1), *IEEE Transactions on Aerospace and Electronic Systems* (1), *IEEE Transactions on Instrumentation and Measurement* (3) and *IEEE Transactions on Vehicular Technology* (2). They are used outside the IEEE in Nature's *Microsystems & Nanoengineering* (14), Hindawi's *International Journal of Antennas and Propagation* (5) and Springer's *Journal of Infrared, Millimeter, and Terahertz Waves* (5). They are found in Austria in *E&I* (3) and outside, e.g. they are used in the *Electronic Letters* (2) of the Institution of Engineering and Technology (IET) and in *Science* (3) of the American Association for the Advancement of Science (AAAS). This list is by no means comprehensive. Typical examples are shown in Fig. 1.

Microsystems & Nanoengineering is of interest, because the first engineering journal from the Nature Publishing Group



(a) (b) (c) (d)

Fig. 1. Typical examples of coins used as measure of size. a) Fig. 2 from [11] (©2016 IEEE), b) Fig. 2 from [12] (©2016 IEEE), c) Fig. 3 from [13] (©2016 IEEE) and d) Fig. 3 from [14] (©2016 IEEE). All images are reused with permission.

[15] is a relatively young journal with a manageable amount of publications. At the time of writing[1] fourteen out of 142 published articles (9.86 %) in the journal used coins as measure of size.

III. Common Practices in Using Coins as Size Measure

Qualitative analysis reveals a form of unwritten consensus in the scientific community on how coins should be used as measure of size. The rules of using coins as measure of size are formulated. The rules are formulated such that they express the common usage among the referenced publications. Only counterexamples are given, meaning that all investigated works that are not explicitly mentioned support the rule. A counterexample is created if none is available as a reference.

Rule 1. *Coins are used as a measure of size.*

Placing coins next to objects in photos is more than a rough size reference ("coin-sized"). The geometries of coins are standardized by the issuing authority. Placing a coin next to an object is a true measurement of the object's size, similar to rulers or cubes with 1 cm side length.

Arguably, this is not the case when coins can not be uniquely identified, e.g. in [16, Fig. 1b] and [17, Fig. 1a]. Both use coins that depict Elizabeth II; in [16, Fig. 1b] "ELIZABETH II D G REG F D 2012" is clearly readable, in [17, Fig. 1a] the image quality is poor, but the portrait of Elizabeth II is recognizable nonetheless. However, in both photographs the material of the coin can not clearly be recognized. Several coins of the pound sterling (GBP) are circularly shaped and depict the portrait of Elizabeth II on the obverse. As the exact sizes of the coins are unknown in [16], [17], the object sizes are not measured. This problem generally arises, when coins can not be identified due to poor image quality, as in [18, Figs. 7,10].

[1]Effective date 2018-08-13

Fig. 2. The length of a wire is measured as 2.5 EUR fifty cent coins.

From the referenced papers it is not evident whether coins are used as a measure of length, area or volume. They qualify as measurement devices for all three, as their whole geometry is standardized. Therefore, coins are generally classified as a measure of size.

Rule 2. *Usage of coins as measure of size is not explicitly stated.*

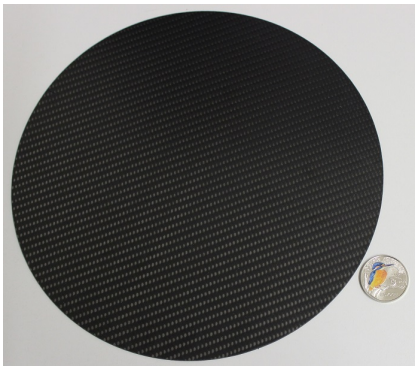
Measures of an object's size are evident for everyone who works in the field and the use of rulers, measurement tape, drawn dimensions, etc. is therefore not typically mentioned in the text. However, as for other measurement devices, there are exceptions where the use of coins is explicitly stated. The most common place to mention the use of coins is in the caption, which is done in ten of the investigated works. Use of coins is explicitly written onto the figure in [9, Fig. 5.4.1] and [19] as "Coin" and "Dime for scale", respectively. [20] comments in the text, "For the first plaster prototypes a thin 800 μm FR4 (flame retardant) PCB with the size of a 2 Euro coin was designed (Fig. 3)."

Rule 3. *Coins are not used as a measurement unit.*

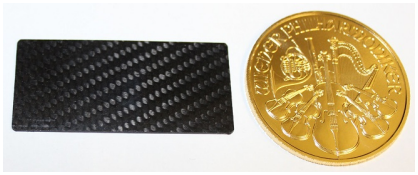
In the referenced papers coins are never used as a true measurement unit, in the sense that neither multiples nor fractions of coins are used. A counterexample is shown in Fig. 2, where the length of a wire is measured as 2.5 EUR fifty cent coins.

Rule 4. *Coins with a small monetary worth are chosen.*

The precise formulation of this rule is somewhat difficult. The used coins are typically common within their country, business strike, and low face values are often preferred. There is no evidence that authors choose expensive or special coins. The rule could be formulated based on coin rarity, but the rarity of a coin is hard to assess, especially as rules 5 and 6 will ensure that globally rare coins are used. The distinction could be made based on face value, but this would include bullion and collector coins with faces values much lower than their market values. Commemorative, bullion and collectors coins are not chosen. The formulation *small monetary worth* emphasizes that pennies (0.01 USD) and EUR one cent coins are chosen, although coins of larger denominations are readily available in these currencies. Rules 5 and 6 ensure that monetary worth only has to be determined within a currency and not globally, which might otherwise introduce dependencies on foreign exchange rates. Counterexamples are given in Fig. 3 with a *Tiertaler* collector coin (3 EUR) and a *Wiener Philharmoniker* bullion coin (100 EUR, 1 XAU).



(a)



(b)

Fig. 3. a) The size of a twill-weave carbon fiber reinforced polymer reflector [21] is measured with a kingfisher *Tiertaler* (3 EUR). b) The size of a carbon fiber reinforced polymer sample [22] is measured with a *Wiener Philharmoniker* (100 EUR, 1 XAU).

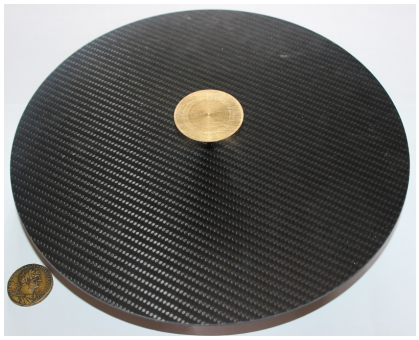


Fig. 4. The size of a conical monopole antenna on a carbon fiber reinforced polymer ground-plane [30] is measured with a sesterce (not ISO 4217).

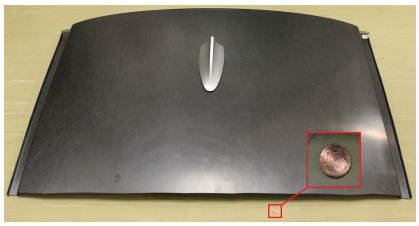


Fig. 5. The size of an automotive antenna module on a car roof piece [31] is measured with a EUR one cent coin.

Rule 5. *Coins are chosen from an author's country.*

Coins are selected from an author's country. The affiliated countries are the ones given by the authors in the referenced papers. Twelve papers use coins from countries other than any of the authors' affiliations. This rule does not apply when figures are reused, e.g.: [23, Figs. 4a and 4b] are reused in [24, Fig. 16a], in both images quarter dollars (0.25 USD) are used. The authors' affiliations in [24] is Spain, in [23] the authors' affiliations are USA. [25, Fig. 2] uses a 1 EUR coin. The figure is reused from [26, Fig. 14]. Coincidentally, the authors from [25] are from the Netherlands, but [25, Fig. 7] is reused from [27, Fig. 7] where a 1 CAD coin is shown. In [28, Fig. 23a] authors affiliated with India reuse [29, Fig. 3b], where a 1 CNY coin is displayed.

Rule 6. *Coins are chosen from the first author's country.*

This rule is tighter than the previous one. The first author's country is again the affiliation given in the paper. Nine papers use coins from affiliated countries of authors other than the first author in addition to the counterexamples to rule 5.

Rule 7. *Contemporary coins are used.*

Coins are selected only from currencies that were in circulation when the referenced papers were published. A counterexample is given in Fig. 4. The coin is a Roman sesterce, 119-121 anno Domini (AD) that shows emperor Hadrian on the obverse. It is used to measure the size of a conical monopole antenna, which is placed on a ground plane made from carbon fiber reinforced polymer - work that was performed in 2016 and published in 2017 [30].

Rule 8. *Coins are used as a measure of size only for coin-sized objects.*

When measuring length or size, it makes sense to choose an appropriate measurement devise. One would not measure the size of a house with a caliper, or the size of a microchip with a surveyor's wheel. Coins are only used to measure the size of coin-sized objects. A counterexample is given in Fig. 5, where an automotive antenna module on a piece of carbon fiber reinforced car roof [31] is measured with a EUR one cent coin.

Rule 9. *Coins are placed next to objects.*

Sometimes, coins are placed behind objects (2), in front of objects (2), under objects (6), and on objects (4). In [32, Fig. 1] a microscale pressure sensing system is placed on the edge of a nickel (0.05 USD). In some publications the coins are placed on less important parts of the objects, e.g. a substrate (7), a metal sheet (3) or under a temperature sensor tag [33, Fig. 6b]. In [18, Figs. 7 and 10] the coins are placed next to the objects, but behind graphs, which are superimposed on the photographs.

Rule 10. *Coins are used as measure of size in photographs and only in photographs.*

In [9, Fig. 5.4.1] and [19] photographs of coins are placed next to sketches. Coins are placed next to photographs of the objects and measured curves are superimposed on the photos in [18, Figs. 7 and 10].

Rule 11. *Coins are not used as lower and upper bound of size.*

Typically, an object will be smaller or larger than a coin. Coins are then used either as a lower or as an upper bound of size. A counterexample is given in Fig. 6 where the size of a 1 EUR coin is measured to be larger than a 20 EUR cent

Fig. 6. The size of a one EUR coin is measured by giving the lower and upper bound on its size as $0.2\,\text{EUR} < 1\,\text{EUR} < 0.5\,\text{EUR}$.

coin and smaller than a 50 EUR cent coin. The example is chosen such that it highlights other peculiar properties of coin based size measurements. First, coins are not part of a coherent measurement system. Second, measurements of size based on coins are not linear, e.g. $2 \cdot 0.5\,\text{EUR} \neq 1\,\text{EUR}$. Third, and most surprisingly, they are not even ordered, e.g. the size of a $0.5\,\text{EUR}$ coin is larger than that of a $1\,\text{EUR}$ coin, although its face value is smaller.

Rule 12. *Coin properties other than size are not used.*

The geometry, material and face value of coins are standardized by the issuing authority. It follows that a number of derived coin properties are therefore also set, e.g. electrical conductivity and resistivity, mass and density. Typically, only the size of coins is used. A counterexample is available in [34, Fig. 7], where the geometry of coins is used, but not to measure the size of objects. Specifically, the depth information of a Lithuanian LTL 2 centai coin is measured with a terahertz imaging system. The geometry of the depicted Lithuanian coat of arms is given and the accuracy of the imaging system can therefore be derived from the measurement.

Rule 13. *The displayed side of the coin is a currency specific preference.*

There seems to be no consensus which side of the coin should be visible. 36 of the USD coins in the investigated papers are shown on the obverse and 18 USD coins are shown on the reverse. Out of the EUR coins used in the investigated papers only [35, Fig. 5] is shown on the obverse. 76 EUR coins are shown on the reverse. For CNY coins no preference is apparent from the sample. 12 coins are shown on the obverse and 12 coins are shown on the reverse. Or maybe the visible side of the coin is decided by coin flip.

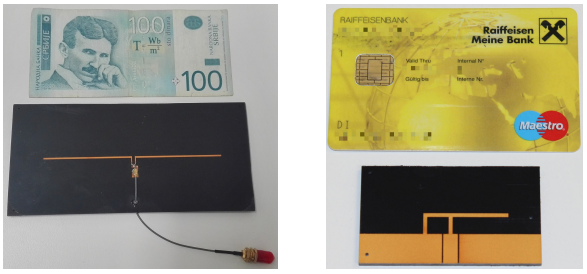
Rule 14. *Representations of currencies other than coins are not used.*

Counterexamples are given in Fig. 7. Fig. 7a shows the size of a dipole antenna [36] measured with a 100 RSD banknote. In Fig. 7b the size of an inverted-F antenna [37] is measured with a cash card.

IV. Predictions

Rule 15. *Adherence to coin measure rules correlates with better paper quality.*

Even if these rules were previously unwritten, they were evident to experts working in the field. A deep understanding of a technical subject would therefore be correlated to a deep understanding of the rules on coin usage. In simple terms:



(a) (b)

Fig. 7. a) The size of a dipole antenna [36] is measured with a hundred dinar (100 RSD) banknote. b) The size of an inverted-F antenna [37] is measured with a cash card.

If someone has been working (and contributing) a lot in this field of research, they would have both a better understanding in this scientific field and a better understanding of coin usage. Adherence to coin measure rules in a publication will therefore be positively correlated with performance indicators. This prediction is fortified by the large number of photographs with coins reused in review articles.

Rule 16. *Coins are preferred to other objects with standardized geometry due to their monetary value.*

Other objects with standardized size certainly exist, e.g. paper sizes in ISO 216, ISO 68-1 metric screws or postage stamps. While examples of non-coin-objects are mentioned in [1]–[5], none of these uses are common. This immediately raises the question why coins are chosen over alternatives. The author's speculation is that coins are chosen for their monetary value. The intent of scientists using coins is to display that they have created something coin sized with a value much larger than the coin it is compared to. This rule is strengthened by rule 4, but it is speculative at this time and must be tested in future work.

V. Conclusion

Coins are widely used as measure of size in scientific works. The habit is customary throughout journals, countries and fields of research.

Coins lack several requirements of modern unit and measurement systems. Authors use coins from their own country, as coins are not standardized worldwide. Coins are not used as lower and upper bound. Coins are not used as measurement unit. Coins do not form a coherent system. Systems that fulfill these requirements already exist. One such example is the Système international d'unités (SI). Devices that use the SI are cheap and available. The author suggests to increase their usage.

Acknowledgment

The historic coin in Fig. 4 was provided by the Münzkabinett of Kunsthistorisches Museum Wien, Vienna, Austria, where it is archived as *RÖ 9762*. A description is available online at http://www.ikmk.at/object?id=ID61872. The author thanks K. Vondrovec of the KHM Münzkabinett for selecting a historic coin.

Currency codes are given according to the ISO 4217 standard.

REFERENCES

[1] Y. Xiao, Y. Xu, H. Sun, X. Xu and A. Zhou, "A Precise Real-Time Delay Calibration Method for Navigation Satellite Transceiver," in *IEEE Transactions on Instrumentation and Measurement*, vol. 65, no. 11, pp. 2578-2586, 2016.

[2] A. Putnam et al., "A Reconfigurable Fabric for Accelerating Large-Scale Datacenter Services," in *IEEE Micro*, vol. 35, no. 3, pp. 10-22, 2015.

[3] "compact power" in *Electronics Letters*, vol. 52, no. 21, p. 1737, 2016.

[4] S. Maci, "Per-Simon Kildal: Friend, Scientist, Educator, Entrepreneur," in *European Conference on Antennas and Propagation (EuCAP)*, Paris, France, 2017.

[5] S. Churkin and L. Anishchenko, "Millimeter-wave radar for vital signs monitoring," in *IEEE International Conference on Microwaves, Communications, Antennas and Electronic Systems (COMCAS)*, Tel Aviv, Israel, 2015.

[6] M. Wnuk and L. Nowosielski, "Multisystem Antenna for Applications in WiFi Networks," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[7] A. Vorobyov, C. Henemann and Ph. Dallemagne, "Liquid Metal Based Antenna for Wearable Electronic," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[8] M. Szymkiewicz, Y. Konkel, C. Hartwanger and M. Schneider, "Ku-Band Sidearm Orthomode Transducer Manufactured by Additive Layer Manufacturing," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[9] P. Choi et al., "An Experimental Coin-Sized Radio for Extremely Low Power WPAN (IEEE802.15.4) Application at 2.4GHz," in *IEEE International Solid-State Circuits Conference (ISSCC)*, San Francisco, California, USA, 2003.

[10] "Coins as Measure of Size," *IEEE DataPort*, DOI: 10.21227/4rhj-3w36, 2019.

[11] L. Gong, K. Y. Chan and R. Ramer, "Substrate Integrated Waveguide H-Plane Horn Antenna With Improved Front-to-Back Ratio and Reduced Sidelobe Level," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1835-1838, 2016.

[12] R. Colella, A. Esposito, L. Catarinucci and L. Tarricone, "Programming UHF RFID Systems for the Internet of Things," in *IEEE Antennas and Propagation Magazine*, vol. 58, no. 2, pp. 109-119, 2016.

[13] E. G. Bakhoum, M. H. M. Cheng and R. A. Kyle, "Low-Cost, High-Accuracy Method and Apparatus for Detecting Meat Spoilage," in *IEEE Transactions on Instrumentation and Measurement*, vol. 65, no. 7, pp. 1707-1715, 2016.

[14] Y. Liu, Y. Chen, H. Lin, and F.H. Juwono, "A Novel Differentially Fed Compact Dual-Band Implantable Antenna for Biotelemetry Applications," *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1791-1794, 2016.

[15] "The First Engineering Journal from Nature Publishing Group: Microsystems & Nanoengineering," in *Microsystems & Nanoengineering*, vol. 1, 2015.

[16] S. F. Jilani and A. Alomainy, "Planar Millimeter-Wave Antenna on Low-Cost Flexible PET Substrate for 5G Applications," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[17] R. Bharadwaj, C. Parini and A. Alomainy, "Analytical and Experimental Investigations on Ultrawideband Pulse Width and Shape Effect on the Accuracy of 3-D Localization," in *IEEE Antennas and Wireless Propagation Letters*, vol. 15, pp. 1116-1119, 2016.

[18] Ji-Xu Zhu, Peng Bai and Jia-Fu Wang, "Ultrasmall Dual-Band Metamaterial Antennas Based on Asymmetrical Hybrid Resonators," in *International Journal of Antennas and Propagation*, vol. 2016, 2016.

[19] P.R. Gibson and R.E. Burgell, "Illuminating dark depths," *Science*, vol. 360, no. 6391, pp. 856-857, 2018.

[20] C. Kollegger, C. Steffan, P. Greiner, M. Wiessflecker, G. Holweg and B. Deutschmann, "Intelligent plaster for accurate body temperature monitoring and investigations regarding EMI using near-field magnetic scan," in *e&i Elektrotechnik & Informationstechnik*, vol. 133, no. 1, pp. 25-31, 2016.

[21] G. Artner, E. Zöchmann, S. Pratschner, M. Lerch, M. Rupp and C. F. Mecklenbräuker, "Angle-dependent reflectivity of twill-weave carbon fibre reinforced polymer for millimetre waves," *Electronics Letters*, vol. 54, no. 6, pp. 359-361, 2018.

[22] G. Artner, P. K. Gentner, J. Nicolics and C. F. Mecklenbräuker, "Carbon Fiber Reinforced Polymer With Shredded Fibers: Quasi-Isotropic Material Properties and Antenna Performance," *International Journal of Antennas and Propagation*, Volume 2017, Article ID 6152651, 2017.

[23] J. H. Choi, P. W. C. Hon and T. Itoh, "Dispersion Analysis and Design of Planar Electromagnetic Bandgap Ground Plane for Broadband Common-Mode Suppression," in *IEEE Microwave and Wireless Components Letters*, vol. 24, no. 11, pp. 772-774, 2014.

[24] F. Martín, J. Naqui, A. Fernández-Prieto, P. Vélez, J. Bonache, J. Martel and F. Medina, "The Beauty of Symmetry," in *IEEE Microwave Magazine*, vol. 18, no. 1, pp. 42-55, 2017.

[25] N. Haider, D. Caratelli, and A. G. Yarovoy, "Recent Developments in Reconfigurable and Multiband Antenna Technology," in *International Journal of Antennas and Propagation*, vol. 2013, 2013.

[26] K. R. Boyle and P. G. Steeneken, "A Five-Band Reconfigurable PIFA for Mobile Phones," in *IEEE Transactions on Antennas and Propagation*, vol. 55, no. 11, pp. 3300-3309, 2007.

[27] S. V. Hum and H. Y. Xiong, "Analysis and Design of a Differentially-Fed Frequency Agile Microstrip Patch Antenna," in *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 10, pp. 3122-3130, 2010.

[28] M. K. Khandelwal, B. K. Kanaujia and S. Kumar, "Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends," in *International Journal of Antennas and Propagation*, vol. 2017, 2017.

[29] Yu Lin Zhang, Wei Hong, Ke Wu, Ji Xin Chen and Hong Jun Tang, "Novel substrate integrated waveguide cavity filter with defected ground structure," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 53, no. 4, pp. 1280-1287, 2005.

[30] G. Artner, R. Langwieser and C. F. Mecklenbräuker, "Carbon Fiber Reinforced Polymer as Antenna Ground Plane Material Up to 10 GHz," *European Conference on Antennas and Propagation (EuCAP)*, Paris, France, 2017.

[31] G. Artner and R. Langwieser, "Performance of an Automotive Antenna Module on a Carbon-Fiber Composite Car Roof," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[32] P. Pannuto et al., "MBus: A System Integration Bus for the Modular Microscale Computing Class," in *IEEE Micro*, vol. 36, no. 3, pp. 60-70, 2016.

[33] S. Lopez-Soriano, I. P. Spassovsky, J. Parron and G. Marrocco, "Electromagnetic Feasibility of a Passive Wireless Sensor Network for Temperature Mapping Inside a Shielded Enclosure," in *European Conference on Antennas and Propagation (EuCAP)*, Paris, France, 2017.

[34] A. Lisauskas et al., "Exploration of Terahertz Imaging with Silicon MOSFETs," in *Journal of Infrared, Millimeter, and Terahertz Waves*, vol. 35, no. 1, pp. 63-80, 2014.

[35] M. S. Castañer, J. I. G. Fuertes, J. M. S. G. de Olea, R. M. Gallego and J. L. F. Jambrina, "Radial Line Slot Antenna Design for Monopulse Space Debris Radar," in *European Conference on Antennas and Propagation (EuCAP)*, Davos, Switzerland, 2016.

[36] G. Artner, R. Langwieser and C. F. Mecklenbräuker, "A MID Dipole Antenna in LDS Technology," in *24th Telecommunications Forum (TELFOR)*, Belgrade, Serbia, 2016.

[37] G. Artner, R. Langwieser and C. F. Mecklenbräuker, "Concealed CFRP Vehicle Chassis Antenna Cavity," *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 1415 - 1418, 2017.

Gerald Artner (gerald.artner@tuwien.ac.at) is currently with the TÜV AUSTRIA Group, Vienna, Austria. He received the Dr.techn. (Ph.D.) degree in electrical engineering in 2017 from the Technische Universitt Wien, Vienna, Austria, where he worked as University Assistant at the Institute of Telecommunications until 2019. His research interests include electromagnetic compatibility, interference alignment, wireless communication testbeds, vehicular communications, automotive antennas and carbon fiber reinforced polymer in antenna applications.