THE SUSTAINABILITY CONNECTION FOR MOBILE ELECTRONICS

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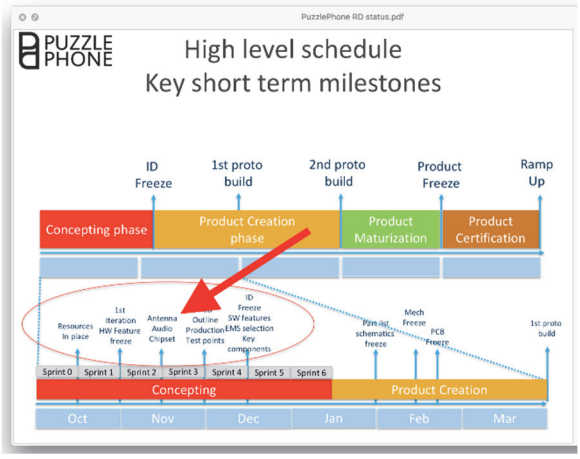
Abstract: Modularity has been identified as a prerequisite to achieve a more circular economy in electronics. In particular it would help to match reusable modules and subassemblies of connectivity enabled products during reuse and repair efforts to keep functional units in active use - concentrating on those, which caused the highest environmental impact during the initial production. This paper introduces the missing link enabling an efficient reuse and customization of more standardized electronic devices. An ecosystem of compatible modules will enable smaller production runs and smaller companies to participate in constantly updated electronic functionalities while concentrating on their unique customized parts of the product (or on software apps and services, as may be the focus of the company).

1. INTRODUCTION

Connectivity is the stepping stone for smartphones, and many other popular and ubiquitous electronic devices. Even though there are different schools and approaches when it comes to the R&D methodology for a new smartphone, and regardless if we are considering an ODM device, or an OEM platform, they all share something in common: within their earlier stages of development all the core radio frequency (RF) related aspects must be checked and sanitized (communication standards, performance, SAR, regulatory compliance).

Figure 1: An example R&D sequence highlighting early selection of RF features and antenna



Thus for modularity of smart products an interface capable of separating the RF frontend from the other core electronic modules has turned out to be a large obstacle. To keep the designs versatile the interface should support a mix of standard digital bus lines and the medium and high frequency signals allocated to RF circuitry.

The expected environmental benefit results from adapting core products to changing RF standards such the upcoming switch to 5G standards.

2. PROJECT BACKGROUND

The Horizon 2020 research project sustainablySMART researches a range of measures along the product life cycle of mobile IT devices in support of a Circular Economy, including reuse and remanufacturing technologies, but also explicitly addressing the design of products. Developing a connector solution for mobile IT, which allows easy exchange and replacement of individual modules, is one key strategy of the project.

Circular Devices Oy is among the project partners and has the core role to create a modular smartphone platform. As one interim outcome a connector sufficiently small, capable, resilient, and compliant with the MIPI Alliance electrical signal specifications has been created. This new connector combines Commercial Off The Shelf solutions (or COTS) with a new invention for efficient high frequency radio signal transport across the connector. The R&D brief

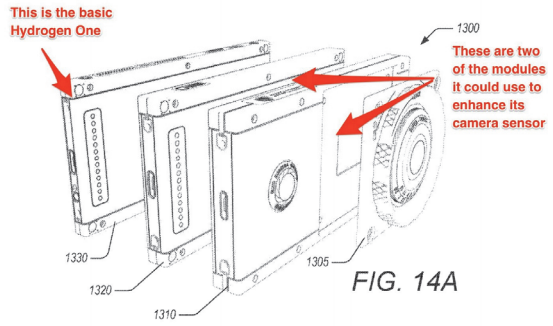
took into consideration market and industrial trends to develop a future proof solution that is also licensable and useful in the countless and increasing number of applications running on the so-called "Androidware" architecture. In essence, the module connector as a standardized interface is now seen as a basis not only for modular smartphone design, but as the beginning for an ecosystem of smart modules, which can be customized into many different IoT devices.

3. MODULARITY FOR 5G EXAMPLE

After years in the making, the 5G standard is finally reaching the stores in the form of 5G ready terminals. Unsurprisingly for the industry experts, these first units reflect how challenging RF is getting as we step into the "millimeter wave" antenna design that some segments of 5G standards require (it should be noted here that 5G is not really a single new standard with one new frequency). A clear example of this is how a big industry player like Motorola, fueled and backed by an even bigger giant like Lenovo, has struggled to launch a standard monolithic – as opposed to modular – 5G smartphone, choosing to go with a 5G module instead for the existing Moto Z3 phone [1].

The concurrence of Moto Mods 5G launch – one of the very few modular smartphones available in the market (currently only Fairphone, Motorola Moto Mods, and the costly RED modular smartphone for professional videographers [2] offer some sort of modularity to the end users) – and the transition from 4G to 5G – a generational change happening only once every 10-15 years – represents a unique industry serendipity that can't be overlooked. This coincidence deserves a closer look as a reference case to position the strategic importance of miniaturized RF connector for modular smartphones, and other modular connected devices – portable or not.

Figure 2: RED Hydrogen One patent filing



In the absence of a product teardown of the Moto Mod 5G internal components by the time of writing this paper, we can only guess based on its size, how the modules look [3] and what the connector looks like internally.

Figure 3: Moto 5G mod and close-up of the module connector [4]

The very welcome story on upgradeability across GSM standards that this Moto Mod tells, it represents also a tale of not so efficient use of materials: a module with a thickness like this one isn't carrying only an antenna or RF frontend. Modem, silicon, and extra battery to run the duplicated electronics are the most likely reason of its bulky appearance. These components already exist in the main module (electronics and screen) hence a duplicity caused by a platform with limited upgradeability is happening in front of our eyes, and it is also harming the overall form factor by increasing the thickness of the device far above what the market has already set up as the acceptable threshold for average end-users – although this might be "ok" for early adopters and professionals with an urgent need for better connectivity.

Motorola Moto Mods modular ecosystem, already in its 2nd generation, is a good example proving how:

- There is an end-user demand big enough for industrial players to bet on the benefits that modularity enables. [5]
- That this approach reduces the R&D friction and costs between legacy technology transitions – leading to faster adoption rates with potentially lower e-Waste generation.
- Even large multinational players can reach out to distributed maker communities by allowing and supporting mods, which do not change the original product [4].
- That there are different ways to understand modularity [6] and each one has different implications for the above mentioned stakeholders (industry, end users, CM/EMS, carriers).

4. INTERNET OF THINGS (IOT) DRIVING MODULAR INTERFACES

Incidentally there are more things happening at the intersection between the Motorola 5G module and the current GSM network. The Internet of Things mesh and mess networks are showing both maturity in terms of which use cases provide real value [7] , what is required from a standardization point of view [8],

and there is already solid evidence from expert analysts [9] on why hybrid connectivity is a must for the future of terminals and networks.

Over the last 12 months a new product category, associated to an emerging spot in the IoT networks topography, has emerged in parallel with the long predicted increase in data traffic due to new and massive IoT networks being deployed [10].

Edge computing and associated "edge computers" are smartified gateways and routers with increased connectivity, and more processing power as a solution for the increasing bottlenecks threatening networks [11] and [12].

> *"Infrastructure Is Becoming Hyper-distributed. Iot involves much more than just the cool "things" being connected. A good architecture includes edge devices, such as Iot gateways, that never existed before because they were unnecessary. Prepare for this reality with holistic system design, automation, and management."* - Sophia I. Vargas and Richard Fichera. 2017.

Under the hood many of these devices run some sort of Linux-ware, which makes them technically capable of running Android too (which runs on an old Linux kernel version). These hardware requirements, pulled by the need for more capable "edge computers", represent an opportunity to offer a modular open standard that can be quickly embraced by all kind of players and turned into a de facto standard in the short term.

The leanest solution possible must satisfy all the requirements and expectations described above (users, integrators, network, etc.) while being 100% aligned with the slow moving pre-existing standardization efforts such as MIPI. The research conducted by Circular Devices and Fraunhofer IZM in sustainablySmart over the last 4 years has shown that a small and resilient enough RF connector is the missing link that opens up the kind of versatile modularity that pleases them all (described as mix & match in [6]).

In line with PuzzlePhone branding of Circular Devices the new solution is dubbed the PuzzleCompatible coax connector.

Figure 4: Cross section of the new RF connector

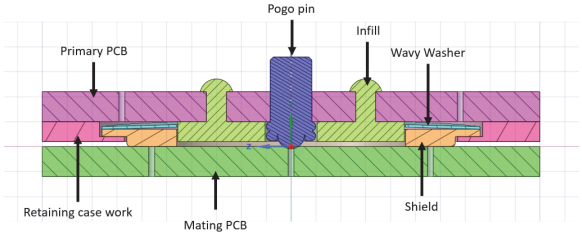
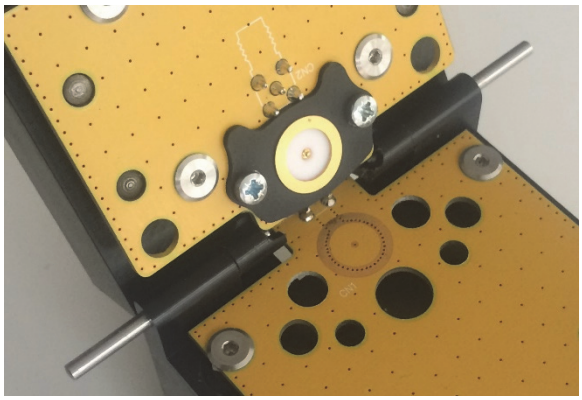


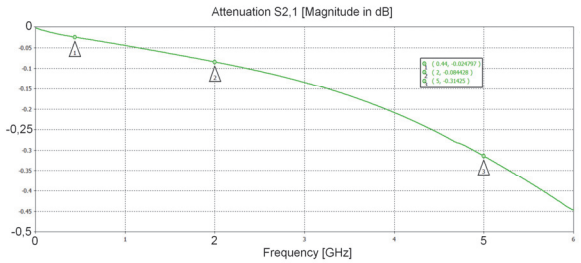
Figure 5: Mechanical test rig showing the new coaxial connector



The connector might not be smaller in footprint than existing RF connectors in mobile devices, but the connection is formed solely through pressing the two parts together and is stable even when the pressure is not as optimally specified and when the connector parts have a small offset. Both cases are very relevant for user exchangeable modules.

Early simulations demonstrated excellent performance from 400 MHz up to 5 GHz. Figure 6 shows the simulation result of the connector including the PCB lines leading to and from the connector. The signal loss of the connector itself is therefore lower than the -0.31 dB at 5GHz shown in the chart. Under laboratory conditions first mechanical lifecycle tests simulating 1000 make-break connections have shown no significant signal loss or component degradation.

Figure 6: Simulation result showing low attenuation up to 5 GHz



All the above has been achieved with a non-linear Coaxial Connector, with a profile of 1.27mm, that is robust and, most significantly for the development of an open hardware ecosystem, lowers the technical barriers to entry by offering relatively low precision manufacture, allowing for low precision alignment, and reducing issues related to mechanical wear.

5. EXPECTED MARKETS

Although the PuzzleCompatible connector Functional Required Specifications matched the average flagship smartphone‘s requirements, and opens the potential for a fully Circular Economy aligned solution, it turns out that the most attractive entry market for the PuzzleCompatible electro-mechanical connecting solution is in the Internet of Things arena.

Having regards to the reports mentioned above on how and where market, user cases, standards, and networks are heading to, it is quite obvious those are all businesses dominated by B2B, B2G, and B2B2G relationships (G being government and government agencies).

The investments made in IoT infrastructures show an ROI that is 100% dependent on “how well it works“, while “the way it looks“ has minor importance. This is just the opposite of what happens for the vast majority of the smartphone market where the foreseeable, and desired change towards a more conscious consumerism is being led by products finding their way into the market with professionals (case of RED Hydrogen), or as part of B2B programs. Hence, conscious consumption designs of smartphones will remain niche products, if they do not emulate the look and features of market leader flagships closely enough.

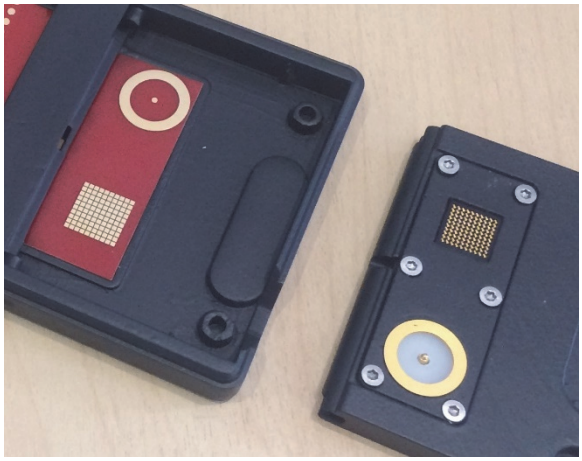
Eventually the smartphone conscious consumers are expected to keep growing, and the good news will be there is a tested solution waiting for them for modularization. Meanwhile the IoT dominant segments are already expecting nothing but serviceable solutions, backed by System Thinking driven by serviceable criteria lowering the total costs of ownership.

In other words: both public and private organizations smartifying their operations by deploying massive flocks of IoT sensors and gateways (e.g.: Smart Cities, or Dark Factories) are, by financial definition, Hardware-as-a-Service oriented clients. And if there is something Circular Economy is about that‘s focusing in having the longest and more serviceable lifespan possible, something that can be achieved with the right type of modularity. In conclusion that is why this inter-module solution is so well aligned with a more conscious and efficient business operations, starting with IoT, and then progressively spreading all across different mobile connected devices.

6. CONCLUSIONS

Somewhat against earlier expectations, a modular interconnect offering intra-module RF connections has been shown to be the greatest obstacle remover in truly modular ICT products. The developed solution might be deployed first for IoT devices before appearing in actual consumer devices like smartphones. Market logic in terms of highest gain and earliest return of invest for a new technology somehow dictates feasible market entry points more than the wish for faster diffusion of sustainable modular consumer products in the mass market.

Figure 7: Test samples for combined module connectors



For IoT the driver of modularity will be reduced costs by keeping the majority of the hardware installation and upgrading only parts of the system. The saving of resources will be incidental, and the overarching question of in which scenarios massive IoT deployment can be net positive for the environment is just entering research and discussions.

However, once such modularity can be established in smartified IoT gateways and in high complexity IoT end devices, chances are that similar communications modules could be transferred to home routers, smart TVs and other devices, which technically last longer than the communication standards remain stable. Modular connectivity could extend the lifetime of such products, resulting in minimized resource wastage and in a more stable attachment to some of the products we own and integrate into our living space.

In parallel, but essentially at a slower timescale, the establishment of a modular smartphone ecosystem with a true mix and match modularity will progress. In addition to expected sustainability gains the thinking is that an open hardware platform would especially benefit the small companies driving forward the Circular Economy.

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