The Development of a Standard Hand Phantom for Wireless Performance Testing: Part 2

This is part two of a three part series. Read part one **[1]**

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Defining the Grip

An informal survey of advertised handsets on the market revealed that they could generally be separated into two categories by width. Devices between 40 to 56 mm wide included most mono-block or “candybar”, fold or “clamshell”, slider, and rotator devices having a telephone-style keypad. By contrast, PDA-style devices with a touch screen or QWERTY keypad were generally wider than 56 mm. The first standard hands were thus designed to grip a 40 mm wide device, with fingers of sufficient material flexibility that they can grip a device of up to 56 mm width.

Figure 2a. Example of a human factors grip study.

This would accommodate practically all “phone-keypad” devices that made up the majority of the market, with a separate hand phantom for wide PDAs. This decision was part of a general compromise between trying to accommodate the maximum variety of devices with a minimum assortment of hand phantoms, while simultaneously keeping the grip designs as representative of observed human grips as possible.

The only way to know for sure how a given phone is likely to be held is to perform a human factors study to record how a large sample of people hold a phone and then attempt to draw statistical conclusions from the data. An example of such a study is given in Figure 2. In such a study, users are asked to hold a test phone in a simulated call without knowing the purpose of the evaluation.

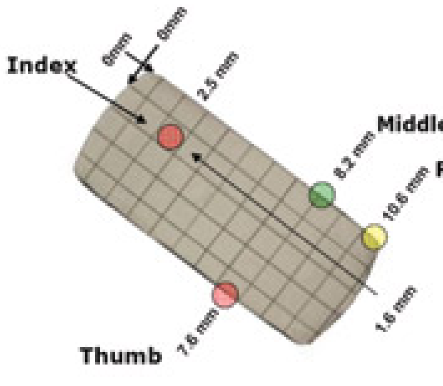


Figure 2b. Exam

Once they have had time to assume a comfortable usage position, photographs are taken to record the position of the phone relative to the head and hand. Later, individual finger locations can be transcribed to a database and the results tabulated to determine the average location of each finger for a wide range of hand sizes and user preferences.

Based on the grip study findings, three grip designs were chosen for 40- to 56-mm wide devices: one for mono-block devices used in a voice call, another for fold devices in a voice call, and a third “data mode” grip, accommodating both form factors when used in interactive modes in which the device is held away from the user’s ear (e.g. web browsing, text messaging, and location based services). For each of these grips, individual finger positioning observations from the grip studies were considered together with learned experience of which finger positionings have the most effect on radiated performance, and practical considerations about the manufacturability and usability of the phantom.

The Mono-block Grip

Design of the mono-block grip proved relatively straightforward due to the devices themselves varying little in their boxy shape, except for overall dimensions. This allowed the closest adherence to human factors recommendations for an “average grip” with a minimum of compromise. Results of the human factors grip studies indicated that (a) the index finger should land on the back of the phone (where it

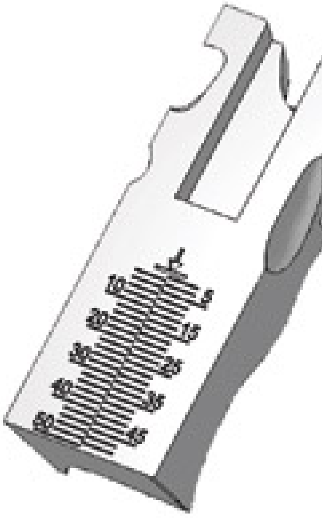
Figure 3. Prototype mono-block grip hand phantom and spacer for holding mono-block phones against the SAM head phantom.

helps to press the earpiece into the user’s ear), (b) the ring finger should contact at the side near the bottom (“chin”) of the device, (c) the palm-to-handset distance should be about 25 mm and (d) there was a preference for a four-finger grip, with the pinky not touching the device.

A foam spacer with a flat surface was designed as a positioning aid to help keep the device at the correct distance away from the palm, since mono-block-style devices share a flat back as a common feature. The flat parts of the foam spacer also provide convenient surfaces for adding touch fasteners, a ruler and other markings to aid with consistent, repeatable positioning of a given device in the grip. This grip is also used with slider and rotator devices.

The Fold Grip

Accommodating hinged devices was more challenging, due to the wide variety of hinge positions and flip angles (10° to 34°) encountered on such devices. A “one-fits-all” grip that would work with any fold device was desired, and it was necessary to balance this goal against the results of the human factors grip studies. The studies indicated that (a) the index finger should land on the flip (where it helps to press the earpiece into the user’s ear), (b) the thumb and middle fingers should land opposed on the base of the phone to “pinch” the device between them, (c) the middle, ring, and pinky fingers should all contact the side of the device in a five-finger grip, and (d) the palm-to-handset spacing should be 35 to 40 mm.



In order to satisfy all these criteria for a device with any likely flip angle, it was necessary to balance the device between the index finger at the flip end, and a rounded foam spacer at the base end. This arrangement supports practically any flip angle by dividing angular variations between the index finger and the base, and helps to keep the middle, ring and pinky fingers aligned along the side of the base by effectively halving the angular variations. Side-view images of dozens of fold devices were superimposed with images of the fingertips, to ensure that all the fingers would land where required for all devices.

This required the middle, ring and pinky fingers of the fold grip to be grouped closer together than in the mono-block grip. The palm-to-handset spacing necessarily varies in this orientation to accommodate the flip angle, especially near the hinge, but is generally maintained around 40 mm near the foam spacer. The rounded foam spacer is even more dependent on touch fasteners and rulings to help keep the device in the correct position, and a custom measuring tool was designed to help identify this position with respect to the device's hinge - the most useful reference feature common to all fold devices. As a final criterion, (e) the index finger was bent somewhat so as not to obstruct a possible antenna extending from the upper-right corner of the base.

The Data Mode Grip

The data mode grip differs from the previous two "talk mode" grips in that the device is not held to the head, and fingers must be held clear of the display area so that it may be viewed by the user. As a result, human factors grip studies indicated that a common data mode grip could be used for both mono-block and fold devices. The conclusions were that (a) the thumb should be located over the round "navigation" key, (b) the index finger should land at the back of the device to oppose the thumb, and (c) the remaining fingers should curl around the device, with the number of fingers in contact being related to the device's length.

phones against the SAM head phantom. The hinge fold is supported between the index fingertip and the rounded palm spacer.)

Figure 5. Prototype fold grip hand phantom for holding fold

A survey of device geometries provided additional criteria that (d) the thumb should float 26 m above the index finger (to avoid activating the keypad during testing for the thickest of likely devices), (e) the index finger should not extend more than 19 mm ahead of the thumb, and (f) the middle finger should not land more than 8 mm behind the thumb. As for the previous cases, a custom device-measuring tool was designed to easily position the device into the grip with correct reference to the location of its navigation key.

The Wide PDA Grip

Grip studies revealed that devices wider than 56 mm (generally PDA and touch screen devices) could be conveniently accommodated by a single grip to cover both primary use cases - voice calls with the device held against the head, and data browsing with the hand alone. The device is gripped with the tip and base of the thumb along one side, and the middle, ring, and pinky fingertips along the other. The index finger contacts the back of the device, as in the previous three narrow grips.

Construction Materials and Dielectric Properties

Just as the dimensions and shape of the hand phantom are critical to ensuring that the placement of an antenna is not unduly influenced by an improperly designed phantom, so too are the electrical and mechanical properties of the hand phantom. Whenever any object is placed within the reactive near field of an antenna, the inherent behavior of the antenna can change radically. This goes beyond just the effect of the object blocking or absorbing a portion of the radiation, since the impedance of the antenna itself is changed.

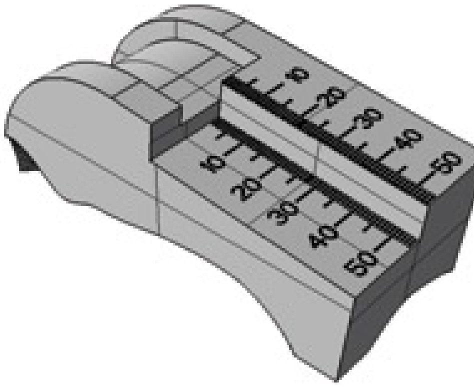


Figure 6. Model of the rounded palm spacer for the fold grip hand phantom. The stepped graduations help prevent parallax error when positioning angled de

This alters the radiation efficiency of the antenna and changes the amount of energy that couples into or out of it. It’s important that the hand phantom have equivalent electrical properties to those of a real human hand to ensure that the same near field effects are seen when using the hand phantom. However, in addition to meeting the required RF properties, the material used to make the hand phantom must remain flexible enough to allow a given hand to adapt to a range of phone sizes and shapes.

While initially the specification of the required dielectric properties seemed to be one of the more straightforward portions of the development process, especially given previous work that has been done in this area [10], recent developments have shown this to be as complicated as any of the other decisions related to the development of a standard hand phantom. Similar to work done to determine the RF properties of the human head when the dielectric fluid used in the SAM Head Phantom was defined, studies have been made to evaluate the dielectric properties of the human hand across a range of frequencies.

One significant difference in developing a hand phantom is the need to allow some flexibility to the hand rather than having a rigid plastic shell. This precludes the use of a liquid dielectric formula in favor of a solid dielectric made from a flexible media such as rubber. While a wide range of formulae have been evaluated, typically consisting of either carbon powder and/or carbon fibers or ferrite powder in a silicone or polyurethane matrix, reproducing the RF properties of a human hand has been difficult.

The difficulties lay not so much in the manufacture of the materials themselves but rather in the available methods for measuring the dielectric properties of a solid. Significantly different permittivity and loss tangents have been measured on samples of the same material using the different methods available. While the open ended coaxial probe method, which uses a reflectivity measurement from an open ended coaxial probe immersed in the dielectric to be measured, is ideally suited for evaluating the dielectric fluids used in the SAM Head Phantom, evaluation of a solid with this method is more prone to error. The flatness of the surface and quality of the surface contact can significantly change the measured result. If the fields at the end of the cable do not travel through a uniform media, the dielectric properties calculated from the reflection measurement will be in error.

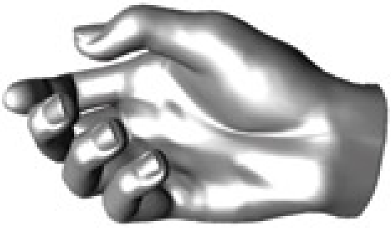


Figure 7. Finished CAD model of data mode grip hand phantom for holding devices in a browsing position.)

Other methods include the use of a waveguide or coaxial transmission lines to perform a transmission measurement through a sample of the material. These methods also suffer limitations in that using a cut sample can still result in air gaps or over-compression that can significantly affect the measured result, while molding the material into the measurement fixture could result in other non-uniformities that could also affect the result. In addition, if the loss through the sample is too high, there is not enough signal measured to be able to accurately evaluate the dielectric constant, meaning that the sample size must be limited to ensure sufficient signal strength.

These issues are further complicated by the nature of the materials themselves. Many of the lossy materials (carbon dust/fiber, and ferrite) used to impregnate the rubber matrix are colloidal in nature and thus are not uniform on a microscopic scale. Therefore, the RF properties of a small sample could be significantly different than the average performance of a larger piece of the material.

In addition, separation or orientation of the materials can occur near the surface of the mold which leads to the potential for differences in the RF properties at the surface of the molded part vs. that throughout the center. This also affects measurements of molded sample blocks vs. blocks that are cut out of a larger part.

While the dielectric properties published by Gabriel [10] have been chosen as the target values for the standard hand phantom, the implementation of these into the final product is still ongoing. Phantom hand manufacturers will have to address these measurement issues in order to be able to manufacture hands that meet the specified criteria.

Figure 8. Preliminary CAD model of wide PDA grip hand phantom, for holding devices either against the SAM head phantom or in a browsing position.

Beyond the dielectric properties of the phantom hand, its mechanical properties are important as well. If the hand is too rigid, it will not adapt to the variety of phones to be tested, and will tend to press buttons on the sides of devices or push the device so that it no longer rests on its alignment spacer. However, if the hand is too flexible, it will not hold the desired shape and measurement reproducibility will be compromised.

The dielectric mixture complicates matters further, since too much powder impregnated in the hand can cause it to crumble into pieces or make it so rigid that it cracks when flexed. In addition to remaining flexible the hand phantom should be able to withstand years of use without degrading. Finding a mixture that meets the target dielectric requirements and still has the desired mechanical properties is as much an art as a science.

Conclusion

With the culmination of several years of dedicated work by a multi-discipline R&D team, a set of standardized hand phantoms are ready to be made available to the market for use in radiated performance testing of mobile wireless devices. Through an attention to detail and consideration of a tremendous number of factors, these hands were developed on a technical and statistical basis that will ensure their usefulness for a wide range of applications, protocols, and test frequencies for the foreseeable future. In addition, by standardizing on the kinematic model dimensions and material properties, equivalent hands can be easily developed to address unforeseen usage cases by simply producing the appropriate human factors studies and developing additional grips.

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