Fabric antennas for mobile telephony integrated within clothing

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Abstract: *All sorts of consumer electronics are being integrated into clothing. This paper describes work integrating mobile phone antennas. Conducting fabrics offer antenna performance that is at least as good as conventional antennas, while being inconspicuous and comfortable to wear.*

1. Introduction.

Future clothing may have a variety of consumer electronics products built into the garments.[1] Philips has been working on the enabling technologies for 3 years, and has demonstrated suits with integral radios and phones.[1]

A lot of the research work has been in how electronics can be constructed using a garment's fabric. This paper discusses how mobile phone antennas can be constructed out of textiles.

The paper is arranged as follows. The properties of conventional mobile phone antennas are considered in section 2. The structure of the wearable planar inverted F antenna is described in section 3. The suitability of the various textiles used is considered in section 4. The summary is given in section 5.

2. Conventional mobile phone antennas.

Conventional mobile phones either use whip or helical antennas that extend from the top of the handset, or else use (internal) antennas that are contained within the upper part of the handset. In normal use, the phone is held in the hand, next to the user's ear. Consequently much of the transmitted signal is lost in user irradiation, and the antenna's overall efficiency is low. The efficiency value varies greatly between handsets and the way they are being used. It is estimated that the best phones have an efficiency of 30-50%, while the worst may be only 3-5% efficient.[2]

The low efficiencies due to user absorption could be mitigated by using a fairly large conducting surface (or ground plane), which separates the user's body from the radiating element. This ground plane should be 10cm or more across. But today's mobile phone handsets are too small to hold such a ground plane. However the surface of clothing is many tens of centimetres across, and so presents many opportunities for including an antenna element and ground plane. In the next section some suitable antennas and ground planes are described.

3. Planar inverted F antennas.

Planar inverted F antennas (PIFAs) have been used for many years in mobile phone handsets,[2][3] but only recently have been proposed for use within garments.[4]

Figure 1 shows a simple single band PIFA.[2] In essence, a planar inverted F antenna is a low profile resonant element that is about ¼ wavelength long. When operating, currents oscillate in the inverted L section. The antenna's impedance is determined by where the feed is connected along the L section, and is lowered by connecting the feed nearer the short.

[1] For example, see any of the annual digests of the International Symposium on Wearable Computers.

[2] Multi-band PIFAs can be constructed. These have more than one resonant element built into the inverted L structure. Reference [4] gives an example.

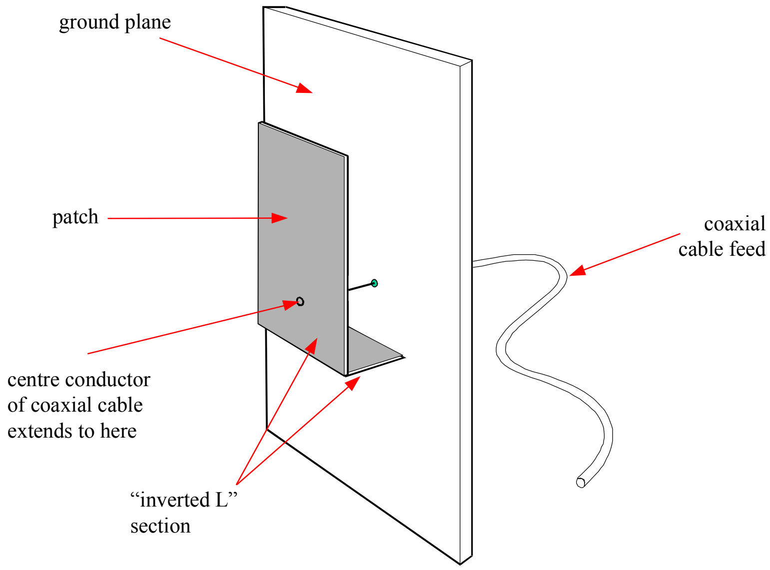

Figure 1 A planar inverted F antenna

Figure 2 shows a GSM900 inverted F antenna constructed from fabric. In this example conducting surface is formed from electrolessly copper plated rip-stop nylon. The short between the top surface and ground plane has been formed by threading the conducting fabric through a slot in the foam sheet spacer. The overall thickness of the antenna assembly is 15mm.

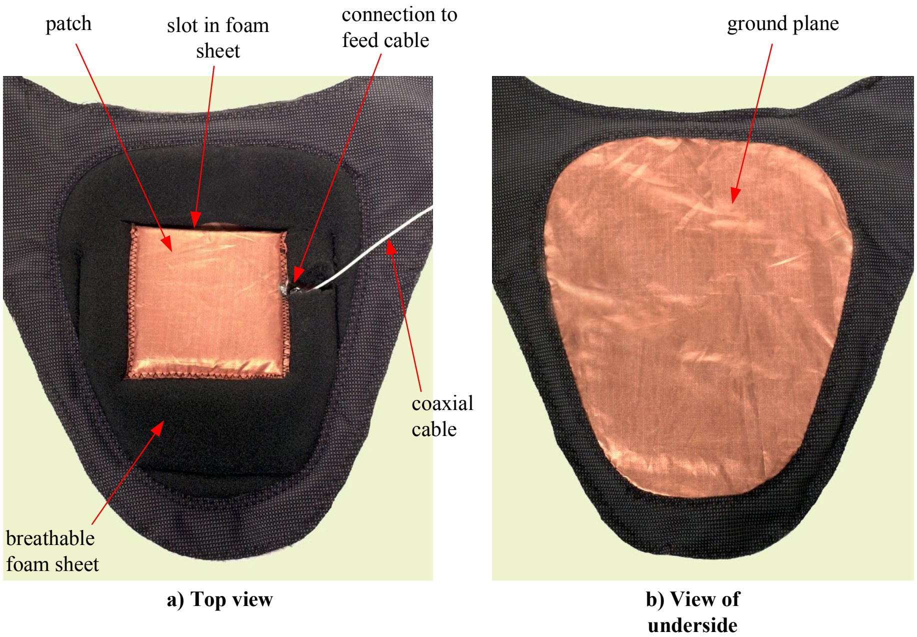

Figure 2 A wearable quarter wavelength patch antenna

For ease of manufacture, the feed is made at the side of the patch. In the figure, the feed is soldered to the conducting fabric. In production versions, the solder contact will be replaced by a patented connector.

As yet there is no workable technology for constructing a long radio frequency feed from cloth, and therefore coaxial cable has been used. The cable shown in the figure is a 1.2mm overall diameter miniature coaxial cable, which is thin enough to be included in men's formal jackets. For a 70cm run between the antenna and mobile phone, the cable loss at GSM900 is about 1.5dB. For many applications thicker cable can be used, which may reduce the cost and signal attenuation.

In normal use, these antenna arrangements have performance equal or better than a mobile phone's extended whip antenna.

4. Fabric technology.

A low loss conductive fabric is critical to the performance of a fabric antenna. This section discusses the performance of a range of conducting textiles.

Textile structures can be divided into a) woven, b) non-woven or pressed fabric, and c) knitted fabrics. Woven fabrics are usually quite dense.[3] Non-woven fabrics are less dense, weaker and lack a regular structure.[4] Knitted fabrics have a low density and are elastic.

Early fabric tests concentrated on fine thread woven and non-woven fabrics that had been electrolessly plated,[5] and on woven fabrics which incorporated conducting threads. Of these, a electrolessly copper plated rip-stop nylon was found to have excellent conductivity, and retained this through normal wear and wash cycles. The non-woven fabric had poorer conductivity, which was possibly due to their looser structure. The early conducting thread woven fabrics were so poor that they could not be used in a resonant antenna.

The interest in knitted cloth stems from their application as a stretchable fabric in constructing a laminated garment. Knitted fabrics can be constructed from pure copper. However using just metal threads tends to damage knitting machines, and most samples were constructed with at least 50% nylon. To date, no antennas constructed with knitted fabrics have had satisfactory performance characteristics.

The reasons for the poor performance of the knitted fabrics have not yet been fully verified. Possible causes include: additional inductance due to using wires, poor contact between the knitted wires, and too little conducting surface in the material (compared with plated woven sheets). Future research is concentrating on using finer knits, and woven conducting clothes.

4. Summary.

Antennas integrated within clothing offer performance that is at least as good as those mounted on conventional handsets. Some electroless copper plated woven fabrics have been identified as ideal for fabric antenna construction. Incorporating this material with a breathable foam dielectric spacer results in an antenna that is both efficient, and also flexible and comfortable to wear.

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[3] Bed sheets and plain shirt material are examples.

[4] Examples include paper and many wadding materials used in suit construction.

[5] Electroless plating is a technique where the metal is deposited from solution directly onto the (specially cleaned) material surface. This gives a much better mechanical bond and radio frequency conductivity than the older electroplating techniques. It is believed that electroless plated rip-stop nylon has better conductivity at radio frequencies than the tracks of electroplated PCBs.

Acknowledgments.

Thanks are due to the whole Wearable Electronics team at Redhill. Particular thanks are due to Clive van Heerden for originally suggesting the concept, Nancy Tilbury and Philippa Wagner for their perserverance, Dr Frances Geesin for identifying fabrics with superb electrical properties, Sonal Parekh for the knitted textiles, and Juliette Alan and Mehmet Amikli for constructing many prototypes,

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