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Deep-Penetrating, Handheld Dielectric Probe for Use in Monitoring Therapy Progress in Rehabilitation Settings

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Tissue dielectric properties are uniquely specific to different tissue types and associated diseases and environmental factors such as heat. Because of this, they are uniquely positioned to be exploited for diagnostic examinations and monitoring. The two most promising means for these types of interrogations are via imaging and point contact with dielectric probes. There are several types of imaging configurations which have been applied in applications such as breast cancer imaging, stroke diagnosis and bone imaging. While these are interesting, their applicability is somewhat limited because of their complexity, size and cost. Equally promising is the potential use of dielectric probes for point contact evaluation. This can be challenging from a range of technical perspectives. The most ubiquitous dielectric probes are the reflection based, open-ended coaxial probes which are commercially available from several vendors. These are convenient with respect to the fact that one only needs to touch the probe to a surface of the tissue, transmit and receive the signal, and read the properties from the associated software. Unfortunately, these are generally limited to laboratory roles since the penetration depth is typically only on the order of ¼ mm and any motion of the feed cables between the probe and measurement device can quickly undermine the calibration.

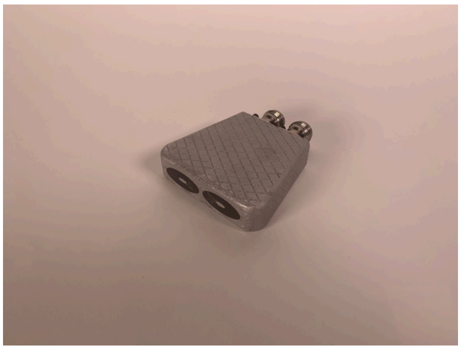

Figure 1. Photograph of the handheld, open-ended coax transmission probe.

We have developed a new transmission-mode dielectric probe which overcomes these limitations to an extent where they are poised for actual in vivo clinical use. Figure 1 shows a photograph of a 3D printed, side-by-side transmission probe which operates from roughly 0.1 – 6.0 GHz. In this case, the obvious counterintuitive features are its strengths. Each elliptical port of the transducer is still an open-ended coaxial line similar to the reflection-based probe. While this naturally implies that most of the signal is reflected back towards the generator, sufficient signal fringes out into the open space to be re-coupled into the receiving open-ended coax. The efficiency is low, but with vector network analyzers readily capable of measuring down to -100 dBm, there is plenty of signal for analysis. Interestingly, while an open circuit would conventionally imply zero bandwidth, the uniformity of the open-circuit load allows us to exploit it over the full range – considerably greater than any conventional antenna. Beyond that, the signals are not sensitive to cable bending which makes it perfect for handheld use.

Most importantly, the signals appear to penetrate several centimeters into the body which is well beyond the limitations of the reflection based probes. In this case, we have performed experiments which demonstrate that it can inform technicians about property content at as much as 2.5 cm in depth. This surpasses a significant threshold when considering clinical use. For the majority of the body, a thin skin layer (around 1-2 mm) covers a subcutaneous fat layer before one gets to the more interesting tissue such as muscle, bone or other organs. For probes that only penetrate a fraction of a mm, they can only really interrogate the skin layer. By being able to penetrate to deeper levels, it becomes possible to examine some of the more relevant tissue.

Our initial explorations are intended to examine bone and muscle – especially in a rehabilitation setting. Non-invasive measurements such as these could be welcomed as quick feedback for assessing whether bone and muscle tone are responding.

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References

[1] P. M. Meaney, T. Rydholm, H. Brisby, "A transmission-based dielectric property probe for clinical applications," *SENSORS*, **18**, 2018, paper # 3484, doi:10.3390/s18103484.