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Urodynamics Measurement by Airborne Ultrasound Doppler System
空中超音波ドプラシステムによるウロダイナミクス計測

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1. Abstract:

In urodynamics study (1a,b), measurements are made on storage phase, voiding reflex, vesical pressure and flow rate during voiding as time-serial flow pattern, and total voiding volume etc., are made. As an external, non-invasive measurement of such pattern typically employs a reception cup, or some setup like a toilet device(s) together with necessary sensors coupled thereon. Unlike such toilet-borne equipment and measurement philosophy we devised a patient born, independent, light-weighted small equipment to perform such measurement at patient's own conduction. We use finger-tip mounted 40KHz airborne ultrasound CW-Doppler device to realize our concept. Our prototype device successfully performed, or feasibility proved, the Doppler spectrum of urinary flow representing its instantaneous flow rate and flow pattern. **Fig.5** shows the scheme of this study.

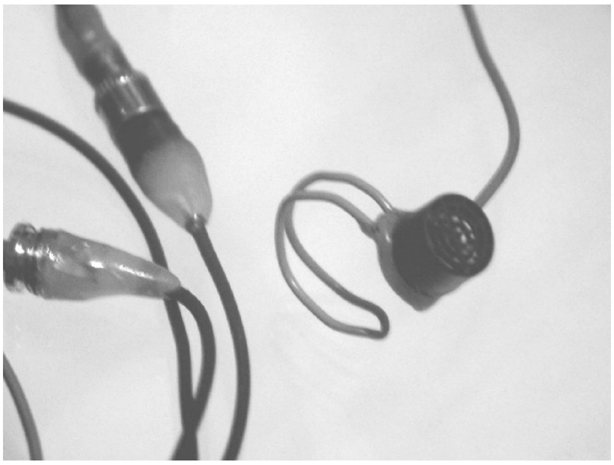


Fig.1: finger-tip mount transducer, diameter=1cm.

2. Method and Equipment

Despite our prior work (2) where 40KHz airborne ultrasound and 24GHz electromagnetic wave are tried co-currently for same purpose as this study, we use airborne ultrasound selectively here. A conical radiator in resonant chamber type piezoelectric transducer (3) is used as transmitter as well as receiver, driven by high-impedance source beside detecting its terminal voltage to yield Doppler-beating echo component at baseband frequency. A single stage low noise audiofrequency amplifier follows via necessary Doppler filtering as a smoothing (high-cut) and low-cut (dc-cut) filter. A/D conversion is performed just after the amplifier. Driving level of the transducer is about 25mW as assumed. The transducer is mounted on finger clip holder as shown in **fig.1**, ultrasound is transmitted and received normally to the finger to monitor outgoing and incoming echogenic targets dorsal to the finger. The transducer has very wide directivity, -3dB cone angle nearly 80 degree. When voiding (urinating) with sustaining one's penis by the finger equipped with this transducer, Doppler-shifted echo from running urea (water) drop can be received and demodulated, and recorded or processed as necessary by following electronic system. Since the echogenicity of water drop in air is sufficiently

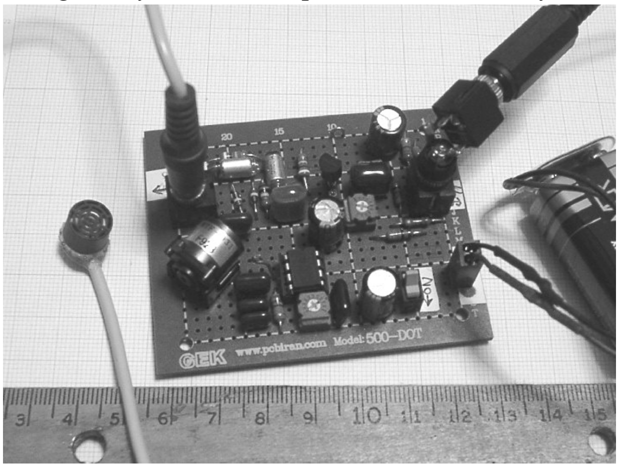
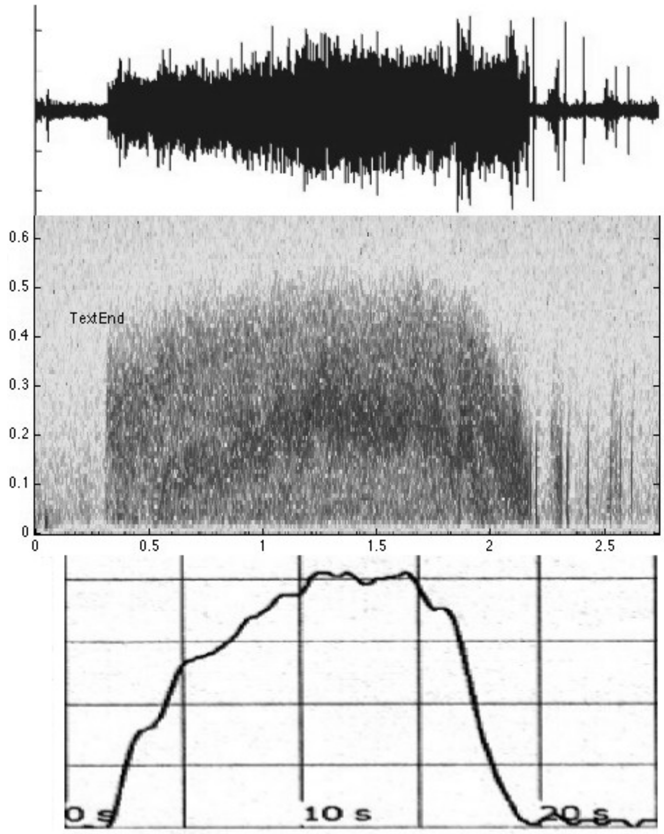


Fig.2: prototype transceiver circuit

strong, system sensitivity is quite sufficient. The prototype Doppler transceiver coupled to built-in A/D converter in PC (Macintosh) is shown in **fig.2**. Following stages of signal processing is performed by Matlab-5 for Macintosh final version.



Fig,3: An example of synchronous presentation of signal (upper), spectrogram (middle) and flow-rate curve (lower) of a voiding process. Horizontal full scale is 25 sec, vertical full scale of spectrogram corresponds to 700Hz Doppler shift or 2.4m/sec. line-of-sight velocity. Full scale of flow rate is 20mL/sec.

3. Physiological Observation(s)

In **fig. 3** an example of Doppler observation of a 30 years old male urination, where signal waveform, its frequency spectrum and flow rate (uroflow) curve, measured simultaneously by conventional device (4), are shown. It could be said that, although observing different aspect of physics of a phenomenon, the Doppler spectrogram and flow rate curve qualitatively meet well to each other. The short-time averaging nature of flow rate curve and almost completely instantaneous nature of Doppler spectrogram seems one of major reason of discrepancy in visual impression.

4. Result and issues to be addressed

The ultrasound part of our prior experience (2) was reproduced using state-of-art transduction technology. The mostly important point is that the sensing and signal processing are performed by patient-born mobile device, not by toilet (or ground) born immobile device. Its feasibility for new style of external urodynamic study or uroflowmetry managed by patient himself (or possibly herself), is proved. Issues left are (a) method to extract uroflow curve substitute from Doppler signal (with calibration, including transducer directivity), (b) possible noise and/or artifact in this measurement, and (c) trials with variety of patients and environments. These will be addressed in time and reported elsewhere in nearest future.

5. References

(1a,b) http://www.sghurol.demon.co.uk/urod/, http://en.wikipedia.org/wiki/Urodynamic_testing

(2) Y.Takeuchi; 13th IRMMW session F1.8, SPIE volume 1039 (1988)

(3) AT40-10BP3 (Nicera), or equivalent.

(4) Medtronics URODYNE(R)-1000, or equivalent.

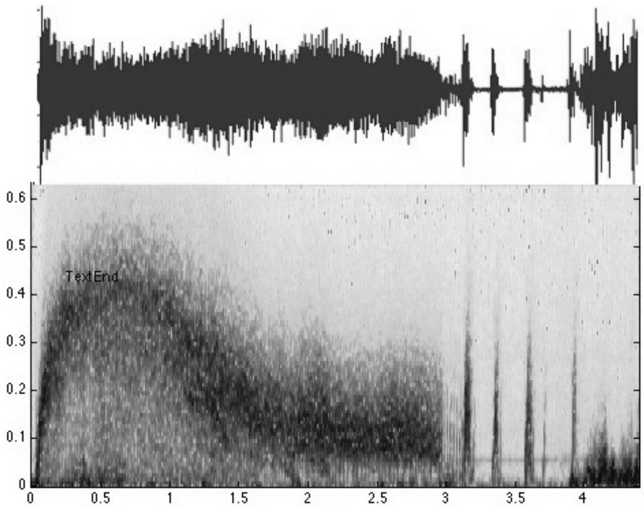


Fig.4 another example of observation. Scales of spectrum are 700Hz(vertical) and 40sec(horizontal).

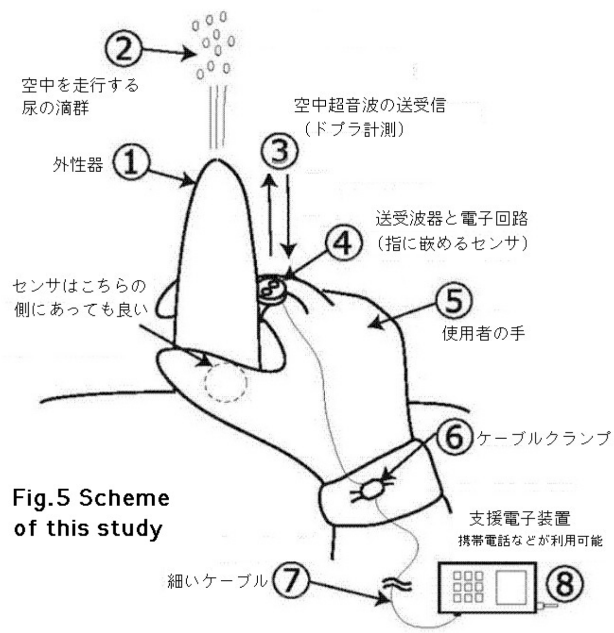


Fig.5 Scheme of this study