K-band Wearable CW-Doppler System for External Urodynamics Study

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Abstract: K-band wearable CW Doppler system is developed for external urodynamics study. The sensor is finger mountable to direct sensing beam parallel to running urea drop in air. It yields audio frequency Doppler signal of the target. The frequency spectrum time pattern allows to estimate speed and flow volume time curve of urination, for urological diagnosis.

Background of the study: In urological field a patient's urination behavior is one of very important diagnostic information for his or her lower urinary tract function. Such examination in non-contact mode is called external urodynamics study, where traditionally a mess-cup or a turbine generator forming a toilet-like instrument accepts patient's urination to record quantity-time curve and/or flow rate mechanically. However, patient must go to such instrumentation toilet at limited installation such as hospital. Natural, undisturbed urination of patient own condition can't be monitored in this way. To cope with this issue our

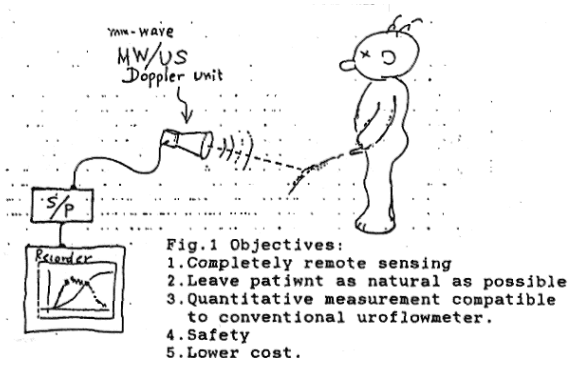

Fig.1: Our 1988 presentation (1)

non-contact, ultrasound and MMW Doppler external urodynamics study systems have been proposed, with feasibility using phantom, in so old days in 1988 at this conference (1), as sketched like fig. 1.

Our renovated instrumentation here presented is to staff it as patient wearable, finger mount device to allow him or her to check own urination pattern daily at anytime, anyplace in own living environment for own practice. Fig.2 shows the scheme. Our earlier system used 40KHz airborne ultrasound as sensing carrier, however, we moved back to K-band MMW for reasons given later.

Method and means: As shown in fig.3, a MMIC stripline resonator oscillator in K-band (24GHz) and homodyne detector diode pair are integrated on one side of a 20mm dia. circuit board where its other side across ground plane is patch antenna pair for transmission and reception. Gross directivity for Doppler sensitivity is so wide as 60 or more degree cone. The Doppler unit is cased by thin plastic (0.75mm polyacetal) enclosure to form finger mountable style. The Doppler audio

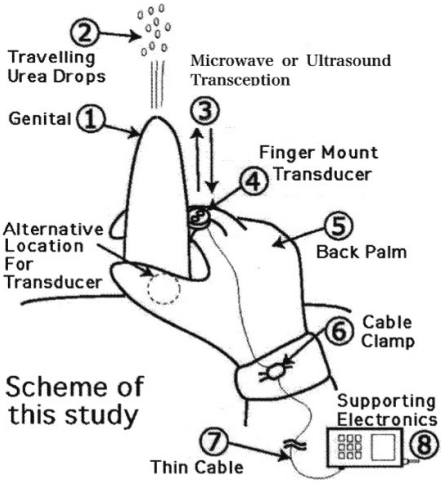

Fig.2: Scheme of our wearable Doppler device

signal at detector diode output is recorded for off-line FFT analysis to have Doppler spectrum and flow rate estimate. For such recording and processing of Doppler signal in prototype development phase, Matlab-5 under Macintosh OS9.2 is used with quite well satisfaction. The ridge trace algorithm is based on adequate 2D-smoothing of the Doppler spectrum image speckle pattern followed by peak tracing with given criteria for

Results: When patient urinates with this device mounted at finger supporting his genital or next to her orifice, a Doppler audio signal and spectrum can be obtained typically like shown in fig.4a,b. A ridge tracing of the spectrum (Fig.4c) yields uroflow curve substitute. Urologist can diagnosis lower urinary tract function based on one-gaze of the Doppler spectrum, even without such uroflow curve substitute. The sensor unit in 2nd prototyping phase is designated for battery operation including wireless transmission of the

Doppler audio signal to recording and signal processing device located proximity. For practical consideration the K-band system is preferred than its ultrasound ancestor (2) for cleaning and disinfection capability because sealed washable design is possible in K-band system while ultrasound ancestor (2) can't.

Summary: K-band finger mount wearable CW Doppler system is developed for external urodynamics study for anytime anywhere natural unconstrained urination in patient own living environment and for own practice. This device, and its gross concept, will make an evolution in clinical urology practice as well as patient conducted own healthcare. Our another report (3) explains this device and its ultrasound ancestor much detail in comparison, while patent support covering external Doppler urrodynamics device in general also has been obtained (4).

Fig.3: Our finger mount Doppler unit and its exploded views.

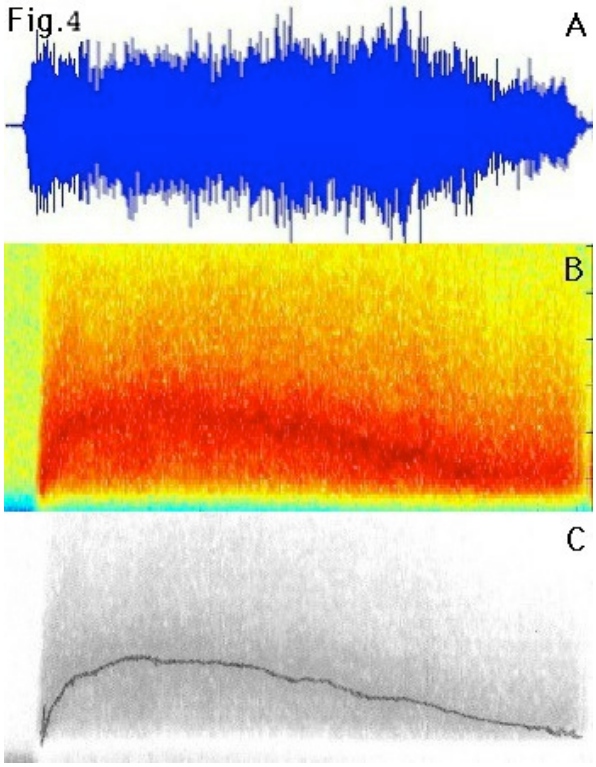

Fig..4a,b,c Doppler signal(a), spectrum(b) and its ridge trace(c) for uroflow curve substitute. Horizontal span is 30 second to cover an entire urination process. Doppler shift axis (b) spans from zero (dc) to about 500Hz (=3m/sec. line-of-sight speed).

References:

(1) Y. Takeuchi, 13th IRMMW, session F1.8, SPIE Volume 1039, 1988
(2) S. Matsumoto et. al., J. Urol., 189, e341(2013), Abstract No. 831
(3) S. Matsumoto et. al., The 40th Remote Sensing Symposium, 2015.3.2, paper #2. The Society of Instrument and Control Engineers.
(4) JP 5553315 B2 2014.7.16 assigned for Kagoshima University and Asahikawa Medical University