

ULTRASOUND TELEMETRY OF FETAL CARDIAC ACTIVITY¹

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Summary Patterns of alterations in fetal heart rate provide the earliest clue of jeopardy of the fetus from umbilical cord compression, abnormal uterine contractions, placental dysfunction or impaired fetal reserve. Correlated with uterine contractions, such patterns provide an index of the condition of the fetus and an objective basis for clinical management. The recognition of the value of continuous monitoring of these parameters has resulted in widespread use of electronic apparatus. Telemetry techniques have proved value as an alternative method of surveillance. A system has been devised for telemetry of fetal cardiac activity detected with ultrasound.

Introduction The use of ultrasound for the detection of fetal heart activity² has broadened the range of applications of electronic techniques employed for monitoring the status of the fetus during pregnancy and labor. With appropriate sensors placed on the abdominal wall, it is now possible to obtain a continuous record of the cardiac rate of the fetus prior to rupture of the amniotic sac when direct attachment of the electrodes to the fetus is impossible or, for other reasons, may not be feasible. Reliable information which may be procured in this manner and measured against universally accepted indices of well-being is essential for the assessment of the condition of the fetus. Concomitant monitoring of the fetal heart rate and uterine contractions adds significantly to the safety of induction or augmentation of labor. Surveillance of these parameters in much the same manner as in an intensive care unit has been shown to have special value in the clinical management of patients when high risk of compromise of fetal reserve exists. It also provides means to observe the fetal cardiac response to medications, anesthetic agents or other factors which

¹ Sponsored by a grant from the Theodore H. Barth Foundation.

² K. H. Mosler, M.D., "A New Ultrasonic Monitor for Use in Obstetrics," *International Journal of Gynaecology and Obstetrics*, vol. 10, number 1, p. 15: January, 1972.

may have a deleterious effect. Alteration in patterns of instantaneous heart rate permit early detection of signs of fetal distress³ and treatment of underlying causative factors.

In previous communications, we have described the development of miniaturized apparatus and a system for radio-telemetry⁴ the fetal electrocardiogram when obtained by standard methods with electrodes placed externally on the abdominal wall or applied directly to the fetus. The purpose of the present communication is to report the development of electronic apparatus for telemetering of continuous fetal heart activity (Fig. 2) detected by ultrasound. A system which has been developed for simultaneous continuous telemetry of uterine activity (Fig. 3) during labor is also described. A series of selected tracings which demonstrate the type of recordings obtained in a wide variety of circumstances is presented.

Methods and Materials To delineate fetal heart activity, the type of ultrasound transducer⁵ which is usually employed consists of a light weight circular disc containing two or more transmitting and receiving crystals. From these crystals, the ultrasound vibrations are transmitted through the abdominal wall at an angle of approximately 4-5degrees at a frequency of 2 MHz with an intensity of about 7-10 milliwatts. The total radiated energy delivered to the fetus is estimated to be less than 2 milliwatts/sq. cm. which assures safety to the mother and to the fetus. Several investigators⁶ have reported that no microscopic injuries were observed with even higher levels of exposure to ultrasound.

Uterine activity associated with contractions of labor is detected by means of the usual tocographic sensor⁷ with modification to allow flexibility in range of sensitivity. This is placed externally on the abdominal wall usually at the level of the uterine fundus. The pressure sensitive transducer permits recording of the onset and duration of uterine contractions. The resultant curve of the contraction does not represent the actual intrauterine pressure. However, in many instances there is a close correlation with that noted by internal catheter methods.

³ E. H. Hon, "An Atlas of Fetal Heart Rate Patterns," Harty Press, Inc., New Haven, 1968.

⁴ Orvan W. Hess, M.D., F.A.C.O.G., "Radio-telemetry of Fetal Heart Energy," *Obstetrics-Gynecology*, pp. 516-521; 1962.

⁵ Corometrics, Inc., Wallingford, Conn.

⁶ R. L. Bernstine, "Safety studies with ultrasonic DoF,)ler technique." *Obstetrics-Gynecology*, 34: 707, 1969.

⁷ Corometrics, Inc., Wallingford, Conn.

FETAL HEART RATE TELEMETRY SYSTEM

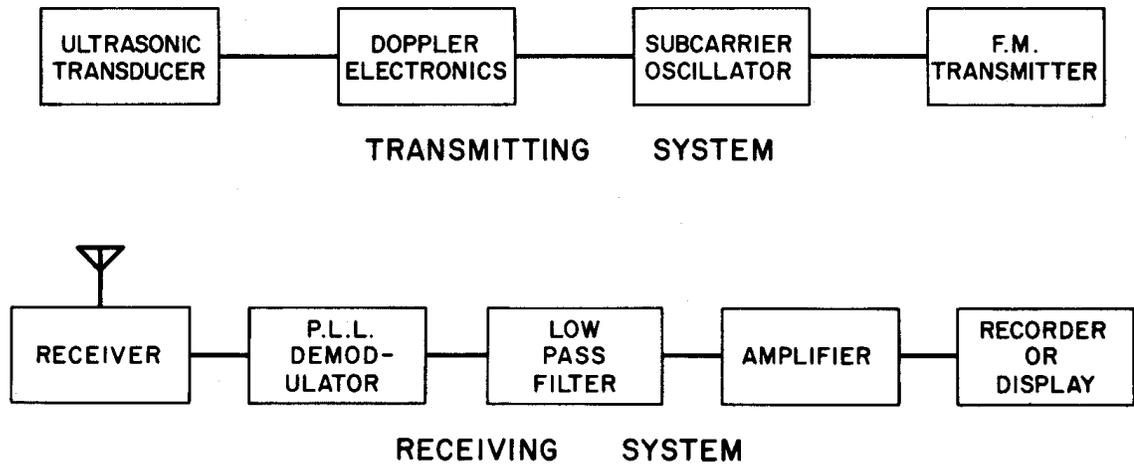


Fig. 2. Diagram of system for radio-telemetry of heart activity detected with ultrasound.

PRESSURE TELEMETRY SYSTEM

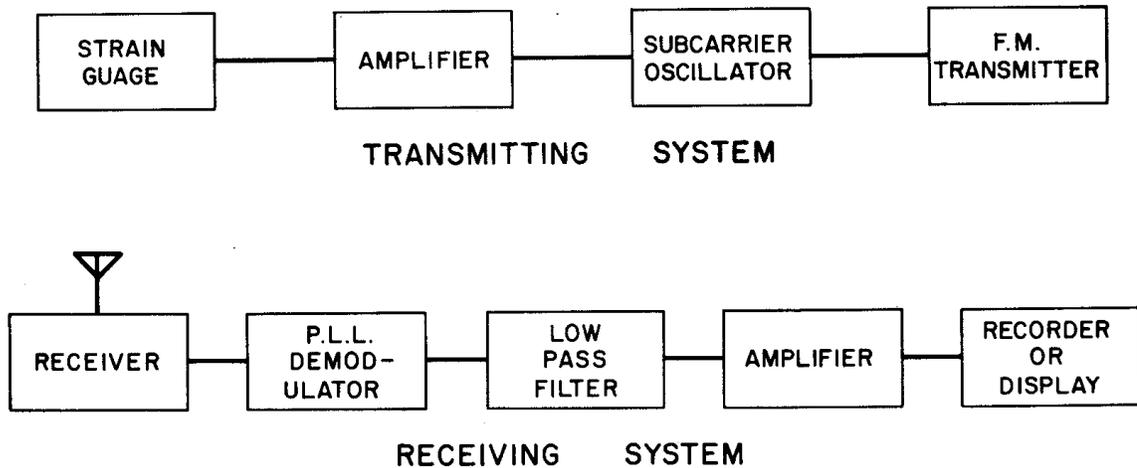


Fig. 3. Diagram of system for radio-telemetry of uterine activity detected with tocograph.

The block diagram (Fig. 1) displays the overall layout of the important or significant components of the transmitting and receiving equipment. The telemetry system has been designed to operate in the 146.94 MHz band employing frequency modulation transmission. Channelized crystal frequency control is used in both the receiver and transmitter operating at a 15 kHz deviation.

2 CHANNEL TELEMETRY TRANSMITTER

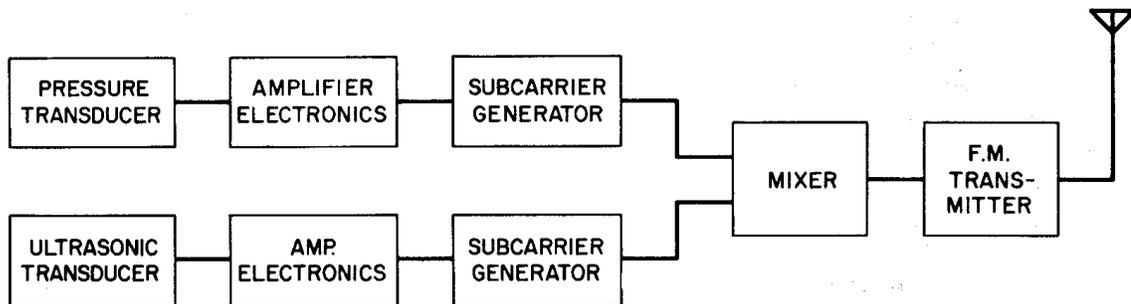


Fig. 1. Block diagram of system for radio-telemetry of fetal heart activity and uterine pressure.

To transmit uterine pressure, the output of a tocograph strain gauge which produces a D.C. voltage which is proportional to the pressure is amplified and applied to a voltage-controlled oscillator (VCO) to produce the sub-carrier. This in turn modulates the radio-frequency transmitter. 160 Hz/sec was selected as the modulating frequency for the pressure channel. The receiver portion of the system is a conventional, commercially available, highly sensitive (.5mv for 20db dual conversion) Kenwood DP202 FM receiver which has been modified as indicated to permit it to discriminate the sub-carrier signal. A phase-lock loop (PLL) type demodulator accomplishes this function. The signal may be further filtered and amplified as required to permit it to operate a recorder⁸ or some type of display unit.

The fetal heart activity is detected on the basis of the Doppler principle by means of the ultrasound instrument via the incorporated transmit and receive crystals and the additional electronics associated with the unit. As in the uterine pressure system, the electrical signals obtained in this manner are fed into a sub-carrier oscillator, modulated and in turn serve to drive the FM transmitter.

The two sub-carrier oscillator outputs are combined and multiplexed to permit the two-channel signal to be transmitted. Possibilities exist for adding other sub-carriers if desired. The RF portion of the transmitter consists of a crystal oscillator which is varactor

⁸ Clinical Monitor-101B, Corometrics, Inc., Wallingford, Conn.

modulated, and operates at 48.98 MHz. This is followed by a tripling stage which places the transmitter on 146.94 MHz. The output is amplified further to produce about one-half watt of power. This was found to be useful for penetrating difficult areas where thick walls or partitions exist. Transmission has been successfully accomplished at distances of 300-500 feet between transmitter and receiver stations.

Discussion Reasonably compact and clinically useful electronic units are widely used for the detection and monitoring of fetal heart rate and uterine pressure with techniques using hardwire between patient and recording equipment. This method usually requires the availability and placement of an individual unit in the labor room of each patient being monitored. The equipment requires a moderate amount of space, and its presence may occasionally be psychologically disturbing. An attendant, either a nurse or physician, must make frequent visits to the room to observe the data being recorded.

Radio-telemetry apparatus offers an alternative system for surveillance. With this method, signals of fetal heart activity and uterine contractions may be relayed from a small bedside transmitter, completely isolated from contact with hospital electrical connections, to remotely located read-out equipment or a central display console.

Linkage may be made from patients situated in a delivery room, distant areas of the hospital or from other regional hospitals to permit taperecording and sophisticated computer analysis.

The feasibility of the use of radio-telemetry when standard techniques of detection of the fetal electrocardiogram and uterine pressure have been employed³ has been previously demonstrated. The apparatus described has been developed for adaptation to the use of external ultrasound and tocograph pressure transducers.

Conclusions Radio-telemetry offers a useful alternative method for clinical monitoring of fetal heart rate and uterine contractions.

A system and instrumentation have been developed for continuous telemetry of fetal heart activity detected by ultrasound.

A system has been devised for multiplexing and simultaneous telemetering of signals associated with changes in uterine pressure.

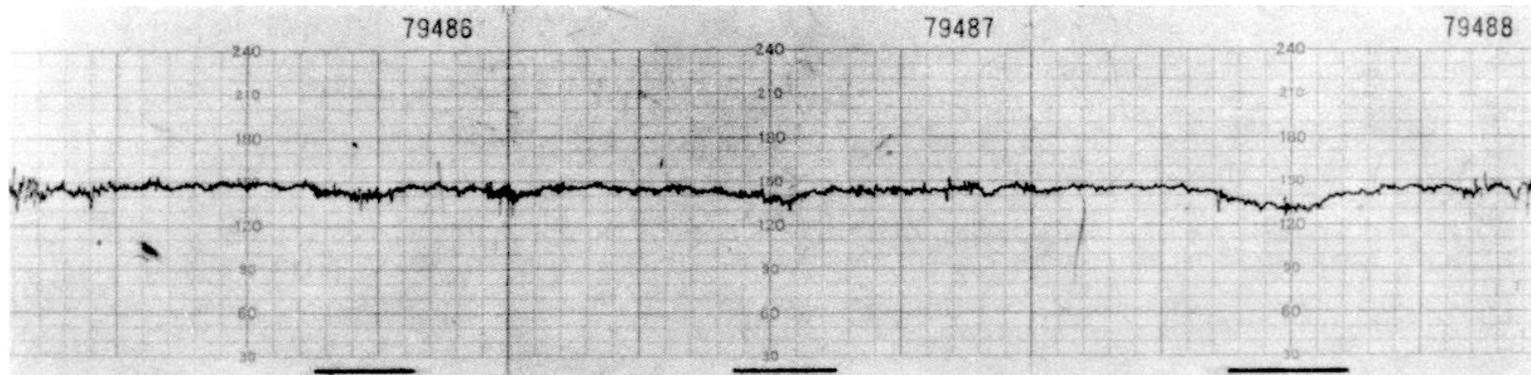


Fig. 4 Tracing of fetal heart rate telemetered during use of ultrasound. Patient in late labor exhibiting mild bradycardia with pattern suggestive of head compression. (Time Scale: 5 Divisions/minute)

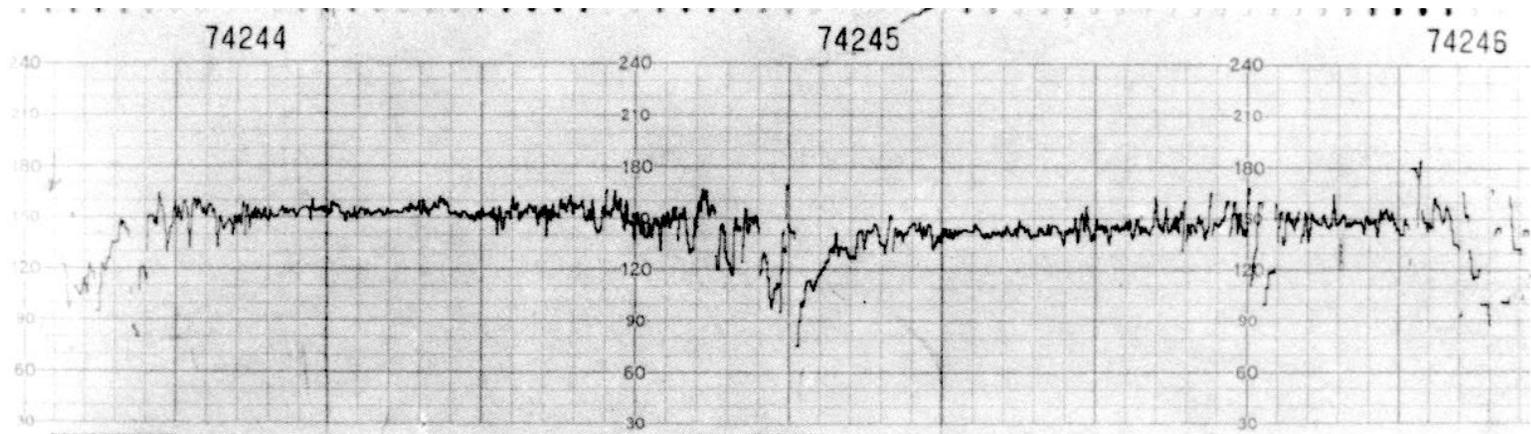


Fig. 5 Tracing of fetal heart rate telemetered during use of ultrasound. Patient in active labor exhibiting bradycardia with uterine contractions suggestive of umbilical cord compression. (Time Scale: 5 Divisions/minute)



Fig. 6 Simultaneously recorded tracings of fetal heart rate and uterine activity during active labor. The upper tracing is the f.h.r. The middle tracing of uterine contraction patterns was recorded with the usual external technique for comparison with that recorded at the same time using telemetry. (Time Scale: 5 Divisions/minute)

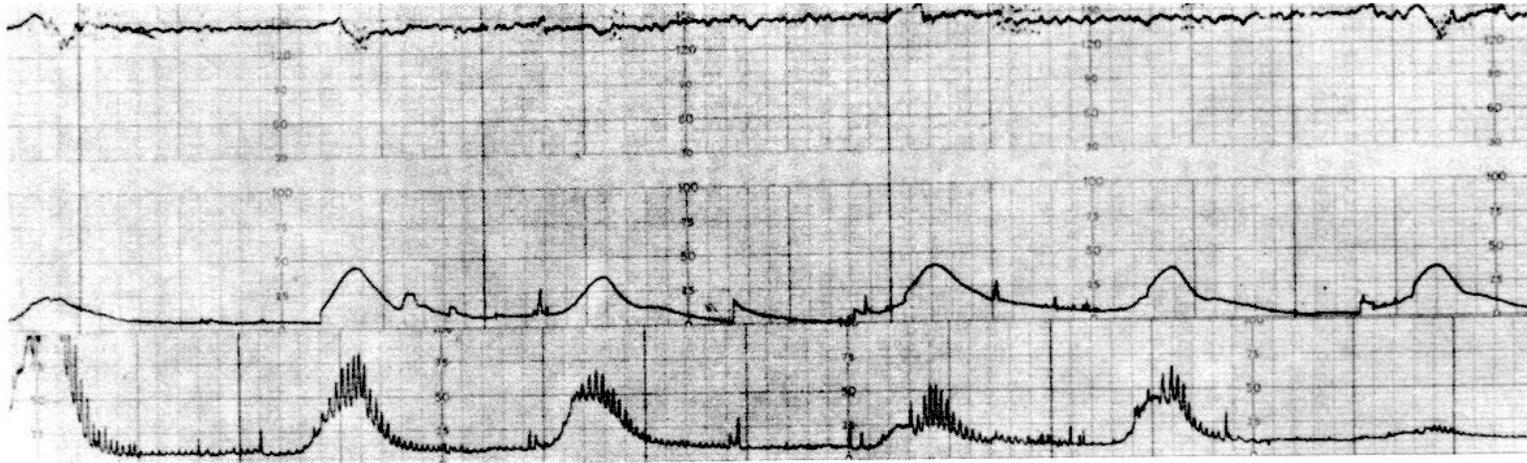


Fig. 7 Simultaneously recorded tracings of fetal heart rate and uterine contractions. The upper tracing is the f.h.r. The middle tracing of uterine contractions was recorded with use of internal (catheter) technique, The lowermost tracing was recorded during telemetering. The progressive decrease noted in amplitude of the contraction curves represents use of built-in adjustable sensitivity control. (Time Scale: 5 Divisions/minute)

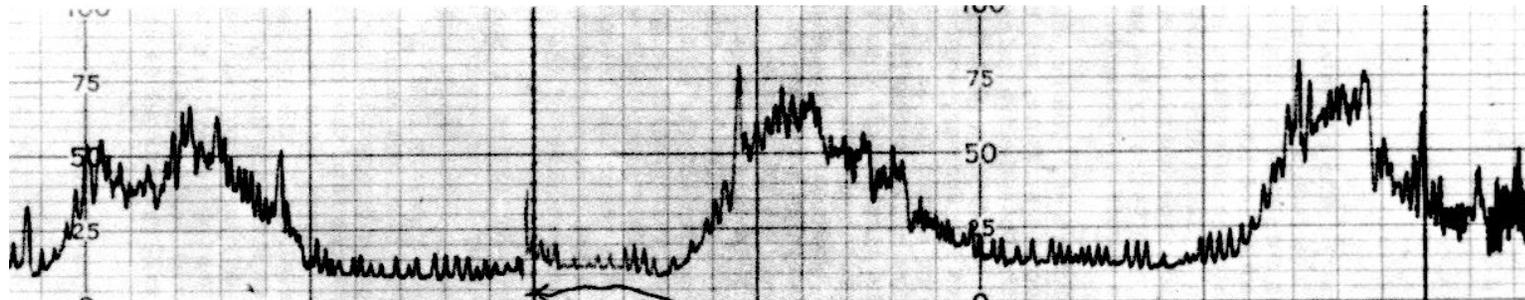


Fig. 8 Tracing of pattern of uterine activity obtained from abdominal wall using tocographic technique after telemetering approximately 300 feet. The sharp intervening peaks noted on the uterine contraction curves represent movements. (Time Scale: 5 Divisions/minute)