Acta orthop. Scandinav. 37, 156–165, 1966.

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TELEMETRY OF MYO-POTENTIALS

A Preliminary Report on Telemetring of Myo-Potentials from Implanted Microcircuits for Servo Control of Powered Prostheses

By

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Received 24.xii.65

The possibility of using myo-electric potentials for control of a powered prosthesis was first realized by *Battye, Nightingale & Whillis* (1955). In a previous paper (*Hirsch, Kaiser & Petersén* 1964) regarding bio-electrical control in a servo-system, we discussed the possibilities and difficulties in using different types of electrodes for receiving the muscle action potentials. We also mentioned the desirability of creating a small electronic circuit for implantation under the skin in order to obtain a closer contact with the muscle and a minimum of disturbance from neighbouring muscles. With such an implanted electrode we would be able to exclude the interference associated with fixation and maintenance of surface electrodes. Recently *Bottomly* (1965) discussed the matching of amplifiers to electrodes showing resistance of up to 200 KOhm.

Regarding an implantable circuit, some properties should be taken into consideration. It should be of a suitable size, probably not exceeding a volume of 0.5 cm^3. It should have a shape with due regard to the electric input terminals and the surrounding tissues. Considering that the implantation will be for a long period, built in batteries must be avoided and the necessary powering be obtained from an external source in the mW power range. Furthermore, the external covering has to be of a material which could be well tolerated by the tissues.

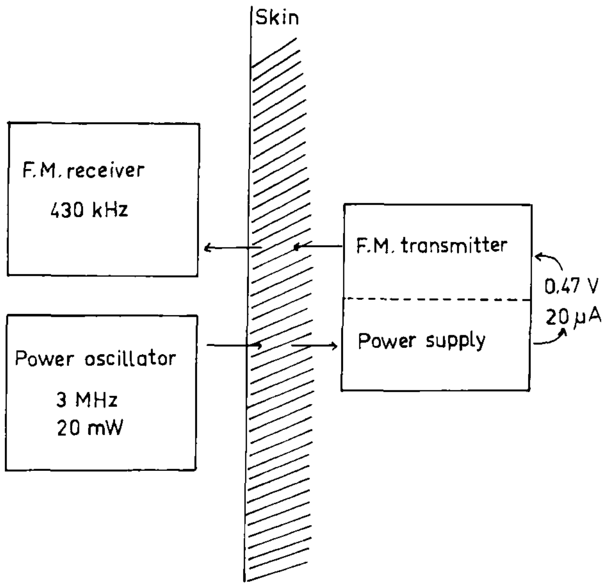

Figure 1. Block diagram, showing on the left the external power oscillator yielding energy to the power receiver of the implanted circuit on the right. This power receiver converts a fraction of the power oscillator output to d.c. voltage, which is energizing an F.M. transmitter. The transformed bio-activity from the F.M. transmitter is received outside the body by an F.M. receiver.

TECHNICAL DESCRIPTION OF THE MICRO-CIRCUIT

The arrangement is shown in the block diagram of Figure 1. An external 3 MHz power oscillator yielding an energy output of about 20 mW is situated on the skin surface at a distance of between 1.5–4 cm from the implanted circuit. The implanted circuit consists of two parts—1/ a power receiver which converts a fraction of the power oscillator output to d. c. voltage, which is energizing 2/ a small transistor oscillator, which is frequency modulated bio-electrically by means of capacitor diodes. The bio-activity is thus transformed to frequency modulated output at a center frequency of 430 kHz, which is received outside the body by means of a F. M. receiver circuit tuned for the said center frequency.

Figure 2 shows a diagram of the micro-circuit. A small center tapped coil 1a and 1b having a ferrite core with a diameter of 1.5 mm, receives energy inductively from the external power source. A small capacitor, 20–30 pF, is used to tune the circuit to the frequency of the

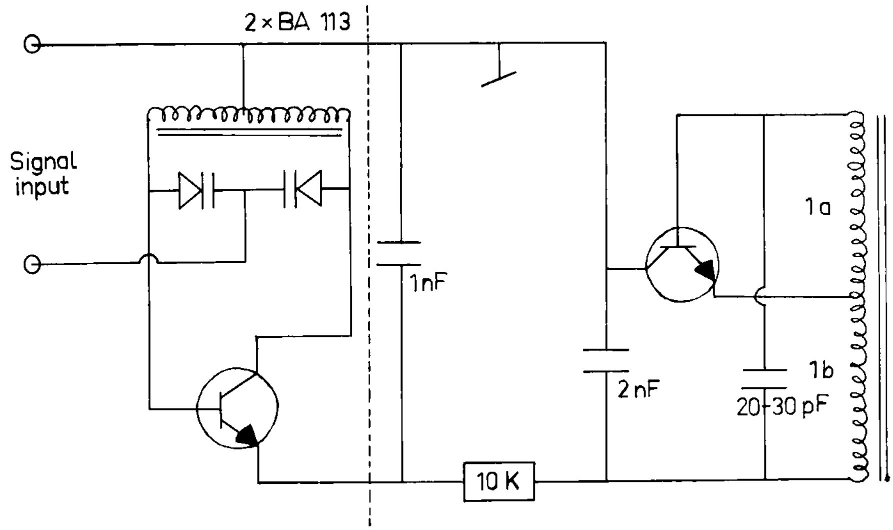

Figure 2. A Diagram of the micro-circuit, fully described in the text.

power oscillator. The coil 1 a provides a steering signal for a miniature epitaxial silicon transistor in such a way that this transistor works as a "controlled rectifier". Only when the base-emitter voltage from the coil 1 a exceeds 0.5 V, can rectification or conduction take place over the emitter-collector circuit of the transistor. Compared to a simple diode arrangement, two advantages have been obtained: 1) the avoidance of a voltage drop of about 0.6 V which would always have taken place over a silicon diode. In the present arrangement the emitter collector voltage drop is less than 0.06 V, provided the necessary steering voltage exists over the base-emitter circuit. The necessary energy in the steering circuit is only a fraction of the corresponding diode loss in a conventional circuit. 2) an effective voltage regulation is obtained because an energy surplus immediately is dissipated over the base-emitter circuit.

Two capacitors, 2nF and 1nF, form together with a 10 KOhm series resistor, the termination of the power supply of the micro-circuit. The F. M. frequency modulated oscillator is connected to two capacitor diodes. The coil of this oscillator is wound on a core of the same type as the receiving coil and center tapped for the input of the supply current. It should be noted that the base and the collector of the transistor oscillator are kept at the same d. c. potential. In this way a very economic and stable circuit is obtained. The necessary feeding

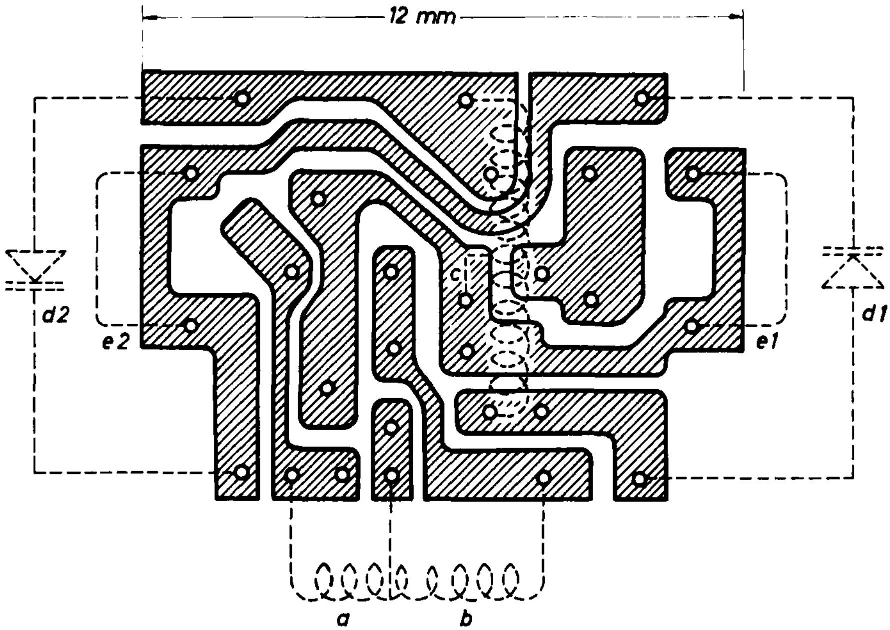

Figure 3. The etched circuits of the implanted system, a–b) a center tapped receiver coil; c) a center tapped transmitter coil: d1–d2) capaciter diodes; e1–e2) input terminals.

voltage is only 0.47 V and it oscillates at a peak to peak voltage of about 0.5 V with a current consumption down to 20 μA. The micro-circuit is nearly drift free. When the distance varies in the transmission range 1.5–4 cm, the total center frequency change is maximum 300 Hz.

Figure 3 shows the etched circuits of the implanted system. As an aid for the reader a few of the components are symbolized: a-b/ the center tapped receiver coil; c/ the center tapped transmitter coil; d1-d2/ the capacitor diodes; e1-e2/ input terminals (U-shaped gold wires 0.35 mm in diameter). The base plate consists of 0.25 mm epoxyglassfibre copper clad laminate with a length of 12 mm and a width of 10 mm. The receiving coil is mounted along the 12 mm edge of the base plate and the transmitting coil is placed perpendicular to the receiving coil.

The geometry of the coil arrangement is shown in Figure 4. In order to obtain a reasonable electromagnetic efficiency, a magnetic concentrator arrangement has been made for the receiving coil and the transmitting coil as well. The receiving coil a-b is terminated by two concentrators g1 and g2. The transmitting coil c uses the core

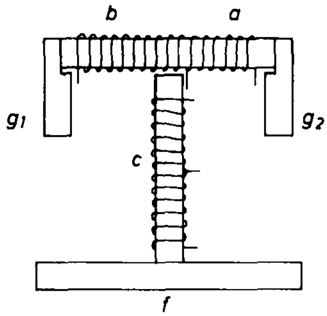

Figure 4. Showing the arrangement of the coils in order to obtain reasonable electromagnetic efficiency, a–b) receiving coil, terminated by two concentrators, g1, g2. c) transmitting coil, using the core of the receiving coil as a concentrator at the one end and a ferrite rod at the other end.

of the receiving coil as concentrator at the one end and a bare ferrite rod as concentrator at the opposite end. This concentrator arrangement improves the receiving and transmitting efficiency by a factor of about 1.5.

In the space between the concentrators are placed commercially available miniature components. After mounting and preliminary tests, the components are embedded in epoxy (araldite) and after final mechanical corrections the whole unit (except the protuding gold electrodes) is reembedded in epoxy.

Initially we intended to use silicone-rubber for the final encapsulation. Unfortunately, the mechanical durability was poor, possibly because this type of rubber has shown an insufficient mechanical resistance around the protruding electrode wires.

PRELIMINARY RESULTS OF A CLINICAL TEST OF THE IMPLANTED MICRO-CIRCUIT

The aggregate has been clinically tested in two persons, the one a volunteer, the other a 30 years old male who two years ago had his right arm amputated about 20 cm distal to the elbow. In both cases the implantation was performed under local anaesthesia. The implant was placed near the extensor muscles immediately superficial to the overlying fascia, at a depth below the skin surface of 1–2 cm. In the volunteer it was removed immediately after having been tested at the laboratory. In the patient the forearm during the first 3–4 days after the operation showed a slight edema at the site of surgery, which thereafter completely disappeared. He had no further discomfort from the

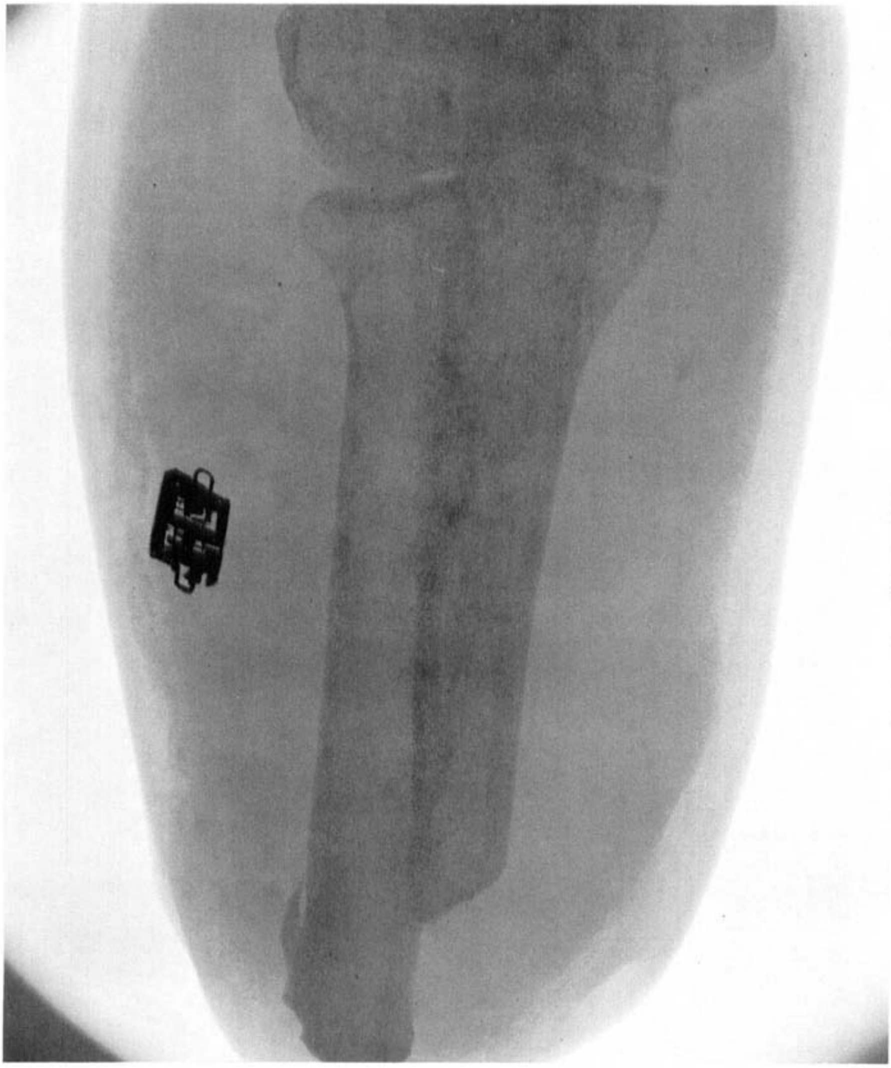

Figure 5. X-ray picture of the implanted aggregate in the patient.

implantation. The implanted micro-circuit was electrically tested immediately and after a period of 10 days. Shortly thereafter the transmitted signals appeared to be of a less satisfactory quality. For that reason it was removed for technical control. It was now observed that the implant was surrounded by a membrane, about 0.2 mm thick. On histologic examination, the membrane was shown to consist of unspecific granulation tissue. Technical control revealed an extraneous

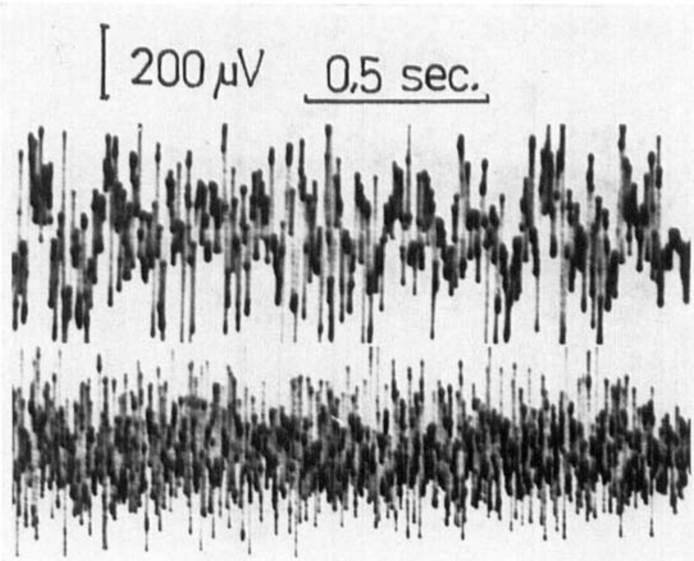

Figure 6. Transmitted bio-electric signals from the voluteer: extensor muscles of the forearm (upper curve) and for comparison the activity obtained via skin electrodes from the same area (lower curve).

shrinkage of the epoxy-material surrounding the micro-circuit, thus exposing this component to severe mechanical stress. This shrinkage may possibly be caused by chemical action in connection with the sterilization procedure (ethylén dioxide).

Figure 5 shows an X-ray picture of the implanted aggregate.

Figure 6 is taken from the volunteer and illustrates a comparison between the transmitted bio-electric activity (upper curve) and the activity obtained via skin electrodes from the same area. The low frequencies are more clearly represented in the upper tracing. During the recording the two EMG's have been analyzed by means of a method described by *Kaiser & Petersén* (1965). In this method the EMG-signals are filtered by means of octave filters, the output of which is used to express the spectral frequency-distribution of the muscle action potentials. The center frequencies of the octave filters were 50 Hz, 200 Hz, 800 Hz and 1600 Hz, and the spectral distribution expressed as the logarithm of the ratio of the different filter outputs compared to the 200 Hz filter output. The visual impression that the low frequency content of the transmitted activity was higher than that obtained via skin electrodes was confirmed. However, according to

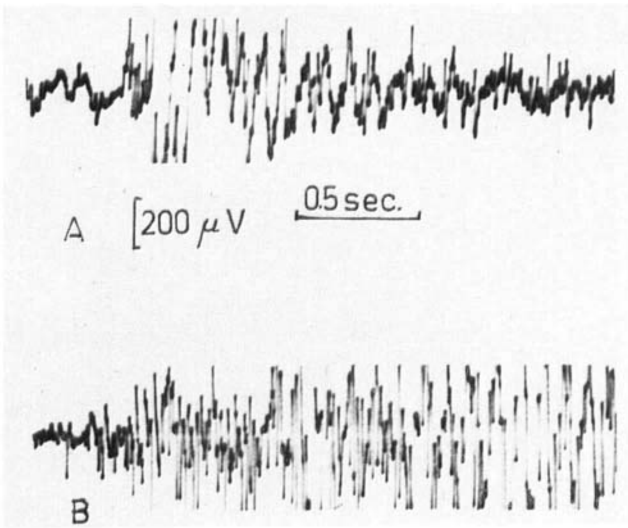

Figure 7. Transmitted activity from the patient (extensor muscles of the forearm) obtained A) one hour after the implantation, B) ten days after the implantation.

an earlier report (*Hirsch, Kaiser & Petersén* 1964), the value of the low frequency spectrum as a source of information is poor. Therefore, it is of greater importance to examine the high frequency portion of the spectrum. From this examination it emerged that the 800 Hz and 1600 Hz activity was far better represented in the transmitted activity. In fact, it was shown that the 800 Hz and 1600 Hz activity was 40 per cent and 300 per cent higher respectively in the activity transmitted from the implant.

Figure 7 illustrates the transmitted activity from the patient. In this case also, the implant was placed in connection with the extensor muscles of the forearm. A shows the activity obtained about one hour after implantation. B shows the activity ten days later. Contrary to the result from the volunteer, the spectral distribution of the transmitted activity from the amputee showed less high-frequency activity than that obtained with skin electrodes. When the analyzed activity in A is compared to that in B, a minor increase in the high frequency output of the latter was detected. This might be due to an increase in the effective electrode area caused by the presence of anaesthetic fluid and edema in close time relation to the surgical procedure.

COMMENTS

Of course, a representative series of amputees must be investigated for a long period in order to state the possible value of external powered implanted micro-circuits for the control of powered prostheses. However, it is apparent from the above that such a type of telemetring is not too difficult to perform. A RF powered implanted unit has been described by *Ko* (1964). This unit consists, however, of two interconnected but separate elements, the one acting as a RF receiver/power supply, the other as a frequency modulated transmitter. The two elements are mechanically and electrically interconnected by means of a 4 cm flexible wire.

In future work, the shape of the implant should be an object of more attention. In order to avoid possible liquid accumulation around the electrodes, these should have the shape of a lens or a bean. At the same time a reduction of the total volume of the implant to about 0.2 or 0.25 cm^3 is desirable and we think possible when changing from conventional miniature components to monolit circuits. It is our intention to have the active elements encapsulated in a miniature glass container in order to avoid a possible degradation of the semiconductors after long-term exposure to tissue fluid.

SUMMARY

A technical description is given of an implantable micro-circuit telemetring myo-potentials for servo control of powered prosthesis.

Preliminary results are given of the clinical observations and the electrical tests of the telemetred myo-signals.

RESUME

Il est donné une description technique d'un micro-circuit implantable télémesurant le myopotentiel du servo-contrôle des prothèses powered.

Des résultats préliminaires sont donnés sur les observations cliniques et les testes électriques des myo-signaux télémesurés.

ZUSAMMENFASSUNG

Eine technische Beschreibung eines einpflanzbaren Mikrostromkreis fernmessen den Myopotentials zur Servokontrol von aufgeladenen Prothesen wird gegeben.

Vorläufige Ergebnisse der klinischen Beobachtungen und der elektrischen Proben der ferngemessenen Myosignale werden gegeben.

This investigation has been supported by grants from the Swedish Medical Research Council, the Insurance Company FOLKSAM and the Medical Society of Gothenburg, Sweden.

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