

The receiver block encloses three separate receivers. These are each constructed on a platinum gold thick film circuit with a circular alumina substrate. The receiving coils are wound around the outside of this substrate. Because the implant operates in a warm saline environment, components are either of the leadless chip type or are hermetically

stimulation suitable for providing bladder emptying, continence or penile erection.

The transmitter block contains three Hartley oscillators encapsulated in epoxy resin contoured to fit the shape of the body. The oscillator at the tip of the block is turned to a carrier frequency of 7 MHz

Before testing the receivers are located under the skin using a tuned circuit finder. The patient's bladder is filled with a known amount of saline and pressure monitoring equipment is connected. Testing is begun by activating each electrode channel at a frequency of 20Hz and noting the effect on bladder pressure and various muscles. The amplitude of each channel is then set to the level required to achieve maximum effect and the stimulating frequency is adjusted to give the best result. If results are adequate the controller can then be tuned for operation.

Once the operation of the stimulator has been established the controller can be tuned to optimise the stimulus parameters for bladder emptying. With the unit set for continuous stimulation, the emptying program DIP switches are adjusted to select the combination of electrodes, pulse height and pulse width give the best rise in bladder pressure. The controller is then set to deliver bursts and the mark space ratio of these is adjusted to give the best flow and to ensure that the bladder is fully emptied. Bursts are typically two to six seconds long with gaps of five to ten seconds between. If the controller is also required to provide suitable patterns of stimulation for continence or erection, the DIP switches for the other programs can be set accordingly.

It has been found that the performance of the device will improve for several months after implantation so it is necessary to retune the controller at regular intervals during this time. After this only an annual checkup for operation and battery replacement is necessary.

## 5. CONCLUSION

We have performed five implants in Christchurch to date. Four of these are operating very satisfactorily and the fifth is still awaiting final tuning. In all cases urinary tract infections have been reduced and urine collecting appliances are unnecessary. Two of our four male patients are now able to achieve erections using the stimulator. There do not appear to have been any complications from the use of the system and all the users have been more than happy with their bionic bladders.

## References

Brindley GS, Polkey CE, and Rushton DN. "Sacral Anterior Root Stimulators For Bladder Control in Paraplegia". (*Paraplegia* Vol. 20 1982)

Ivall T. "Radio Activated Implant for Bladder Control." (*Wireless World*. Jan 1984)

Donaldson PEK. Technical Note: "The Cooper Cable: an implantable cable for neurological prostheses." (*Medical and Biological Engineering and Computing*.)

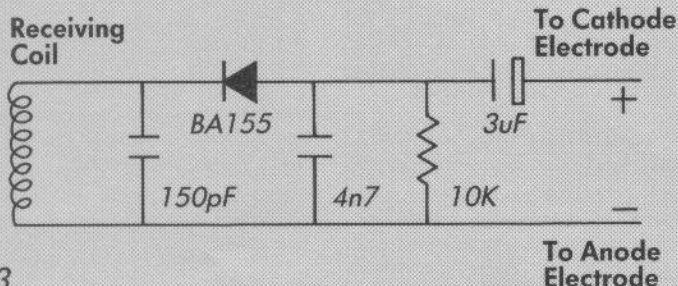


Figure 3.  
Circuit of receiver

sealed in glass, so as to be highly resistant to corrosion. Silicone rubber is used to encapsulate the receivers and great care is taken to see that there are no air pockets between the components and the rubber, as there is a great danger of saline body fluids being absorbed through capillary action.

The circuit of the receiver is actually very simple. (See Figure 3). It consists of a tuned circuit, a diode detector and a filter. The three microfarad series capacitor eliminates gassing through electrolysis at the electrodes.

The receiver and electrodes are connected together by three special cables. These must meet very stringent requirements. As well as being impervious to body fluids and non toxic, they must be able to withstand autoclaving before surgery and will be subjected to stretching, bending, twisting and crushing for many years. A suitable cable has been designed, consisting of four 0.75mm platinum-iridium conductors wound in a helix on a silicon rubber tube. This is covered by an outer layer of silicon rubber, resulting in an overall diameter of only 2mm. A miniature plug and socket are used to join the receiver and electrode cables.

## 3. THE CONTROLLER

The patient is given four pieces of equipment to take home. These are the controller, a transmitter block, a connecting cable and a battery charger. For simplicity the same cable is used for both battery charging and connecting the transmitter block. A program selection switch and an on/off switch are the only controls needed for the patient to operate the controller. The patient simply selects the required program, positions the transmitter block over the receiver site and switches on. The program selection switch is used to select different patterns of

and the other two to carriers of 9 MHz. The rf field strength generated is sufficient to provide 25 volts into a 470 ohm load at the electrodes with a 1cm gap between transmitter and receiver.

Inside the controller adjustments are found for setting the parameters for stimulation. DIP switches are used to set up the functions for each position of the program switch, and preset potentiometers set the frequency, strength and burst duration of the stimulating signals. Power is supplied by five 8.4 volt nickel-cadmium batteries situated beneath the circuit board. Recharging is required about three times per month.

## 4. IMPLANTATION AND TESTING

Surgery is performed in two stages about a week apart. The first stage takes four to five hours and involves the fitting of the electrodes inside the spinal cord. During this procedure the bladder pressure is monitored and the correct nerves are identified by electrical stimulation. The second stage takes about one hour and involves the fitting of the receiver block under the skin on the front of the chest.

The implant can be tested for operation as soon as the next day after the second stage surgery, however swelling around the receiver site means that the results obtained at this stage may not be as good as will be achieved in another two or three weeks time. In fact because of the time taken for the nerve roots to recover from the silent damage caused during surgery, optimum performance may not be achieved for a few months. For this reason the testing procedure may need to be performed a number of times before the stimulator can be put into operation and final tuning can be carried out.