# Remote Tuning for the B44 Receiver Section

## *Using a Variable Capacity Diode*

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IN common with many other mobile operators the writer uses a B44 transceiver in his car. In order to satisfy aesthetic considerations the equipment was relegated to the boot and a remote control system installed. Much thought was given to the method of tuning the receiver and after some experiment a circuit was evolved based on the common practice of substituting a tuned oscillator for the normal 6 Mc/s crystal. No originality is claimed for this approach, which is used by many stations with a fair degree of success, the main restriction being the bandwidth of the first i.f. amplifier which tends to reduce sensitivity at band edges and also that adequate oscillator injection is not always easy to obtain. Nevertheless it formed a satisfactory basis on which to develop a variable capacity diode tuning arrangement and it is this latter aspect of the circuit which is hoped will be of interest to others.

Before describing the circuit itself, some notes on these interesting devices may be of value, particularly as a fuller understanding of their characteristics will allow an adaptation to other equipment or the use of other types of diode which may be more readily available.

### Variable Capacity Diodes

It is a natural property of all semiconductor junctions to exhibit a capacitance across their terminals, the value being some function of the potential difference between those terminals. In many cases this effect is unwanted, a typical example being the way that the input capacitance of, say, a transistor i.f. amplifier changes with the value of applied a.g.c. Steps are usually taken both in the design of the semiconductor device and its associated circuitry to reduce the effect of this capacity change to a minimum.

The variable capacity, Varicap or Varactor, diode is a device in which this effect is encouraged and exploited rather than suppressed and many circuit applications have been found where these components have proved very valuable, mainly in the sphere of automatic frequency control, frequency modulation or harmonic generation—their value lying in the fact that large capacity swings may be obtained at high frequencies with a very good power factor. In terms of frequency control a Varicap diode can operate at frequencies well above the practical limitations of a thermionic reactance valve circuit and is much more convenient, particularly at v.h.f. than a magnetic or ferrite reactance modulator.

For the Varicap to be used as a capacitor of good power factor, it must clearly be operated in a non-conducting condition and it may be shown that the effective capacitance, $C$, with a reverse bias applied, follows the general function:

$$C = \frac{A}{\sqrt{K + V}}$$

where $A$ = a function of area and the material.
where $K$ = a function of the material with the dimensions of a voltage.
and where $V$ = the reverse bias.

Considering this expression it will be seen that as the applied potential increases the capacitance will fall and, also, that the rate of capacity change increases rapidly as the bias voltage tends towards zero. The $C/V$ curve of a typical diffused silicon diode together with other characteristics are reproduced in Fig. 1 and Table 1.

When using a Varicap diode it must never be forgotten that even if it is intended to represent a variable capacitor it nevertheless remains an active component, i.e. it never ceases to be a diode. Therefore as the true potential across the diode can be said to be the algebraic sum of both the control bias and the instantaneous value of the applied signal, then, under normal conditions, the control bias should always exceed the peak value of the voltage in the circuit being controlled otherwise the diode will conduct, rectify and cancel the bias which is being applied to it. Moreover, reverse breakdown (Zener effect) will occur when the sum of bias and signal exceeds the critical potential.

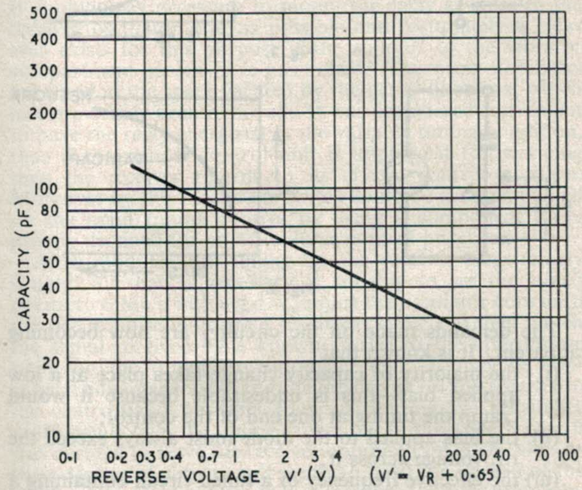


**Fig. 1. Capacitance plotted against reverse voltage for a typical diode.**

Another consideration is that if the applied signal voltage is large, then the instantaneous capacitance presented by the diode to it will vary significantly during the period of the signal voltage. Referring back to Fig. 1, two conditions may be considered; if the applied reverse bias is 3·5V then the capacity of the diode is given as 50pF. Suppose this diode to be in parallel with a tuned circuit with a r.f. signal of a few microvolts applied, then the capacitance will remain so near to 50pF as to be practically constant; if, however, the applied r.f. voltage to the circuit had a peak-to-peak value of,

**TABLE 1**

*Characteristics of a typical diffused silicon diode.*

| | | |
|---|---|---|
| Reverse Capacity $c_R$ $V_R$ = 2V f = 30 Mc/s | 55 ± 10 | pF |
| Series Resistance $r_S$ $V_R$ = 2V f = 30 Mc/s | 1 | ohms |
| Forward Volt drop $V_F$ at $I_F$ = 60mA | <0·8 | V |
| Reverse Breakdown Voltage $BV_R$ | >30 | V |
| Leakage Current $I_R$ $V_R$ = 10V | <100 | nA |
| Loss factor @ 100 Mc/s tan δ | $3 \times 10^{-3}$ | — |

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say, 3V then the instantaneous reverse bias to the diode will vary between 2V and 5V. Reference to Fig. 1 will show that under these conditions the capacitance value will vary between 60pF and 45pF during the period of the cycle. The effect of this will be twofold; one that the effective capacitance will have a different value and, secondly some distortion of the wave shape will take place. It is as a result of this latter effect that variable capacity diodes are used for frequency multiplication, but that is another story . . . !

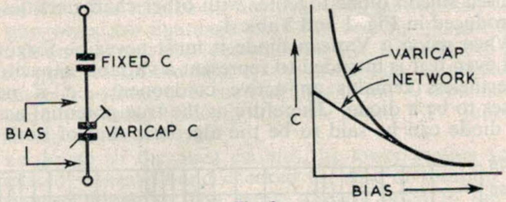


**Fig. 2.**

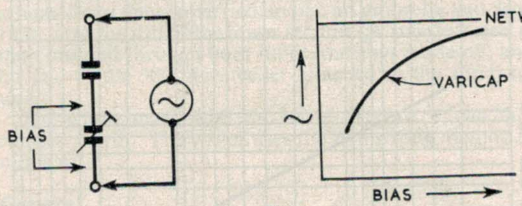


**Fig. 3.**

The demands made on the circuitry are now becoming apparent. It is known that

(i) the majority of capacity change takes place at a low applied bias—this is undesirable because it would cramp the tuning at one end of the control;
(ii) the bias applied to the diode must always exceed the r.f. voltage across it;
(iii) the effective frequency of a tuned circuit containing a Varicap diode becomes a function of the amplitude of the voltage with which it is working.

Considering the first two problems, it is fortunate that a common solution may be found, for if the variable element is placed in series with a fixed capacitor, then a logarithmic variation to the Varicap capacity results in a near linear variation for the series capacity of the network—see Fig. 2. Simultaneously, as the capacity of the Varicap increases (lower applied bias) so it will receive a smaller proportion of the applied voltage to the network— see Fig. 3. By placing the varicap in series with a fixed component in this way a considerable improvement to tuning feel is obtained and the need for high values of standing bias removed.

**Modifying the B44**

As most of the considerable amount of mobile operating in the Sussex and Hampshire area is conducted on a single net frequency it was decided at an early stage that to maintain the crystal tune facility for use when required would be a valuable asset and to facilitate this a miniature relay is used to switch the receiver oscillator grid either to the existing crystal or to a tuned circuit of approximately 6 Mc/s. A spare set of contacts on the relay is used to short circuit the tuning components not in use. This is particularly desirable in the " tuned " case as even when disconnected the high $Q$ crystal can throw a considerable load on the oscillator circuit through stray capacity coupling.

The B44 receiver is used on 4 metres as a double superheterodyne, operating with oscillator low injection at first mixer (crystal times 9) and oscillator high injection at the second mixer (crystal times 3). It may be shown that the tuning range of the receiver becomes the oscillator change multiplied by 12. In fact if the oscillator frequency is $f_o$, the second i.f. frequency is $f_2$, and the signal frequency is $f_s$, then

$$f_o = \frac{f_2 + f_s}{12}$$

Therefore with the 4 metre amateur band extending from 70·1 Mc/s to 70·7 Mc/s—a total width of 600 kc/s—the oscillator is required to change by 50 kc/s. With a second i.f. of 2·6 Mc/s, the actual oscillator limits become 6·06 Mc/s and 6·11 Mc/s approximately.

In choosing the $LC$ ratio of the oscillator circuit consideration was given to several aspects of performance, many

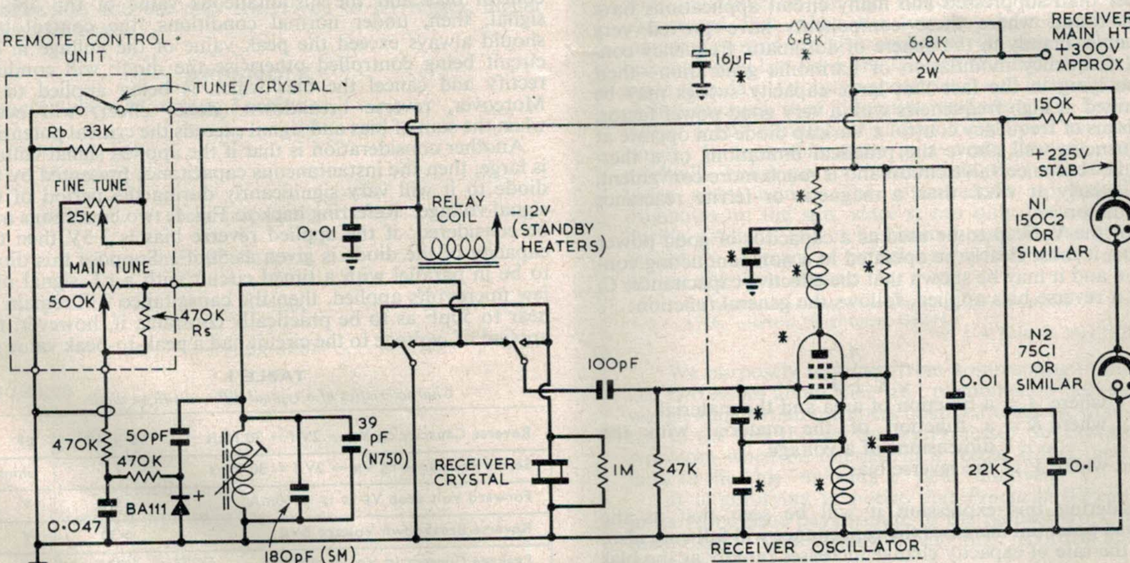


**Fig. 4. The necessary modifications to the B44 for providing remote tuning.**

of which had conflicting requirements, i.e. oscillator injection would be high if the *LC* ratio is high but on the other-hand drift, microphony, and mechanical stability would be impaired. Similarly, in first order terms, as the capacity range of the variable diode is also limited one would expect to have a larger tuning range if the fixed value of the capacitor was low, but fortunately a satisfactory compromise between all these requirements may be achieved. One interesting feature is that if the *LC* ratio is increased beyond a certain point then the tuning range begins to fall; this follows from the fact that the r.f. voltage to the oscillator circuit also increases thus preventing the diode from being biased over its full range. With the values shown a tuning range of approximately 800 kc/s is realized, oscillator injection is adequate, microphony non-existent and it is possible to use the chassis either in or out of the metal case without re-setting the oscillator core.

The revised circuit is shown in Fig. 4.

The diode chosen to effect the capacity swing was a STC BA111 (Fig. 1 and Table 1 refer to this type). It will be noted that the reverse breakdown voltage, $BV_r$, is given as being "exceeding 30V." The maximum potential of the bias control line is accordingly limited to this figure, but in any event there would be no value in trying to exceed this figure as no worthwhile capacity swing would be obtained.

The two neon stabilizers, N1 and N2, are very necessary for mobile operation. A car battery may vary from as low as 10V up to nearly 14V depending on engine speed and the loading imposed by other equipment, such as headlights. The resultant variation in h.t. voltage within a B44 is considerable and stabilization is needed for two purposes, firstly, and most obviously, to clamp the bias control source and, secondly to fix the h.t. supply of the oscillator valve. By this latter means the oscillator amplitude is retained constant which it will be recalled is an essential requirement for frequency stability in circuits of this kind.

The time constant of the control circuit should not be so long as to give a sluggish feel to the tuning, yet should not be so short as to allow random pick-up on the remote control lead to be of sufficient magnitude to cause frequency modulation of the oscillator. In the writer's case the cable from the transceiver to the control position is some 15 ft. long and as an added precaution against this effect, the bias control lead is screened.

Tuning by this method lends itself ideally to electrical bandspread so two potentiometers are fitted in the control box, one for fine tuning after having located a station on the coarse control. A minimum value of bias voltage is determined by $R_G$, which value is just great enough to prevent the diode rectifying the oscillator voltage and cancelling its own bias. Some attempt has been made to correct for residual non-linearity by the shunt resistor $R_S$, though clearly the use of a different law potentiometer or even the same control connected the other way round would modify the value or need for this component.

In all, three B44 receivers have now been modified to this circuit by different amateurs with their own interpretations of an optimum mechanical layout. Performances have been so similar as to indicate that no unduly critical values occur. It is obviously necessary to mount the relay as close to the receiver oscillator grid as possible and fortunately a clear area exists for this purpose if the support to the vibrator compartment screen is re-positioned. The neon stabilizers are fitted in the space vacated by the aerial filter box, which had previously been removed. It was considered convenient to have the relay energized in the variable tuning condition, thus if the remote control unit is unplugged for servicing then the receiver returns to its crystal control position. Moreover by this means the switch could be accommodated on the main tuning control by using a component more usually destined for on/off-volume control purposes.

After modification, tuning up the receiver is extremely simple: all that is necessary is roughly to set the tuned circuit to 6 Mc/s with a g.d.o., adjust the oscillator core until the rise in noise indicates a sensitivity peak and then match the signal received by a known crystal to the appropriate point on the tuning potentiometer dial. It may be considered advantageous to re-tune the first i.f. of the receiver in the centre band position, thus distributing the sensitivity more evenly over the tuning range; but in the writer's case it was decided to leave the receiver optimised on 70·26 Mc/s as the majority of activity still seems to be at the l.f. end of the band. Notwithstanding this, however, a satisfactory performance is still obtainable at the h.f. end of the band and has yielded many worthwhile QSOs at 70·65 Mc/s.

## BOOK REVIEW

**THE DESIGN OF LOW-NOISE TRANSISTOR INPUT CIRCUITS.** By William A. Rheinfelder. 160 pages including 107 diagrams. Published in Great Britain by Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 30s. (Originally published in the USA by Hayden Book Co. Inc., New York.)

This book covers the design of low-noise input circuitry for r.f. and a.f., with particular emphasis on r.f. Although the book is mainly concerned with transistors, reference is frequently made to the application of similar principles to valves. Treatment is aimed at students (which includes radio amateurs), and circuit designers of all levels. A chapter is devoted to descriptions of modern commercial circuitry in the USA and in Germany.

The chapters on the concept and measurement of the noise figure of a receiver are particularly interesting, and have an essentially practical approach to improvements which may be made. An example is the "Tap Circuit" due to R. Cantz of Telefunken, which enables the input circuit of an r.f. stage to be simultaneously noise and power matched, which has the advantage of maintaining a low s.w.r. in the feeder.

The problems of cross-modulation brought about by crowded bands and nearby powerful stations are considered, and the reasons why many communication receivers fail in this important respect are explained and suggestions made for improvement. It is shown how the judicious use of a mismatch between the r.f. and mixer stages will improve both the cross-modulation performance and stability, and how this may be accomplished by use of the "Tap Circuit." The effect of emitter current on the cross-modulation characteristics of transistors is dealt with, together with the possibility of improving the noise figure of a mixer stage by the use of a bridge circuit and neutralization.

While use is made of mathematics, aided by numerous graphs, in putting forward the principles involved, this does not replace lucid explanations and the book may be highly recommended to all who are interested in improving their receiving equipment, whether their main interest lies in the h.f. or v.h.f. bands. W. H. A.

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