Rob's web

RF switching diodes controversy

An april TT item ('RF Switching and Tuning Diodes', p63) drew attention to the series of QST articles by Dr Ulrich Rohde, KA2WEU/ DJ2LR - recognised world-wide as a leading professional expert in HF receiver design - supplemented in a separate OST article by measurements made by Tom Thomson, W0IWJ. These highlighted the shortcomings of some general purpose PN and PIN diodes used for RF switching in some popular amateur HF transceivers. Dr Rohde pointed out that the second order IMD performance could be improved in such cases by substitution of PIN diodes specifically designed for RF purposes, and in particular recommended the Hewlett Packard HP5082-3081.

In part three of his article (QST, July 1994) Dr Rohde gave results of measurements made on unmodified and modified transceivers - an ICOM IC-765, a Yaesu FT890 and a Kenwood TS-50. These measurements suggested significant improvements in second and third order IMD performance. He also evaluated the second-order IMD performance of several other transceivers including Collins KWM-390, TS950SDX, Ten-Tec OMNI VI (second order intercept +43dBm) and FT-1000. But he did not appear to specify which, if any, of this second group would or would not benefit from diode replacement. As a result of his findings, ARRL decided that they would include second-order IMD measurements in future QST Equipment Reviews.

This is highlighted in a letter from Dave Farn, G4HRY, who reported the unfortunate experience of G4KPT who replaced all 40 switching diodes in his Omni VI only to find that sensitivity had suffered. As a result, G4HRY has now replaced the original diodes and believes that "the validity of the original articles is brought into doubt". G4HRY, however, was not able to check on second-order IMD performance before or aftermodification.

While I am sure that Dr Rohde could provide a convincing reply to his criticisms, G4HRY does make some comments that deserve to be aired. He writes:

"G4KPT read the QST articles and as the OMNI VI was specifically mentioned, decided to replace all of the switching diodes in the transceiver front end with HP5082-3081 types. He obtained 40 diodes at a cost of about £1 each and did the modification. This is where the trouble started."

"After completing the modification he noticed that the receiver seemed a little deaf and the S-meter could no longer be calibrated. Thinking he had introduced a fault, he brought the set to me for a second opinion. Tests showed the sensitivity was at least 5dB worse than another OMNI VI. I could not find a hard fault with the rig and decided that, as it had worked well before modification, it was probably something to do with the new diodes. To prove this I built the small jig shown in Fig 1. This enabled diode through-loss to be measured in a 50i2 system which can be equated to diode RF resistance. The jig was used to measure the BA482 types and then the HP PIN diodes. Out of interest, I took a quick look at a variety of other general purpose diodes and this indicated that in respect of through-loss, the original diodes selected by Ten-Tec were a good choice: see Table 1."

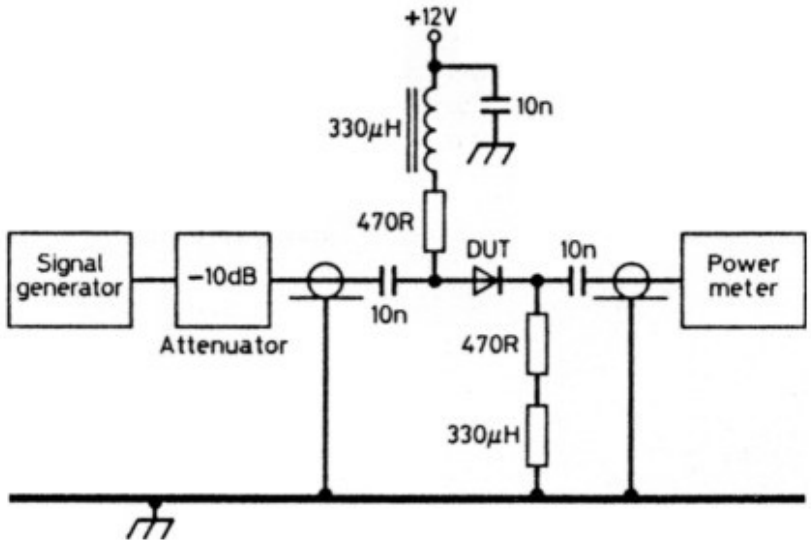

Fig 1: Test set up used by G4HRY to measure the insertion loss of various diodes.

Table 1: G4HRY's measurements of diode loss (dB) in 50Ω transmission path with 10mA forward bias.

Freq	BA482	HP3081	BAT85	1N4148	BA439	1N4007
1.8MHz	-0.6	-0.9				
3.5MHz	-0.4	-0.75				
7MHz	-0.2	-0.7	-0.6	-0.7	-0.55	-0.5
10MHz	-0.3	-0.8				
14MHz	-0.2	-0.9				
18MHz	-0.3	-0.8				
21MHz	-0.3	-0.9				
24.5MHz	-0.3	-0.9				
28MHz	-0.3	-0.98	-0.6	-0.7	-0.55	-0.5

"The receive RF path of the OMNI VI includes 5 diodes before the 1st RF amplifier. The first two isolate the transmitter from the receiver input, the next two select the appropriate bandpass filter. The final diode in the chain feeds the input of the RF amplifier in the Tx/Rx switching. The RF amplifier has 54 parallel-connected FETs with ar input impedance of about 22i2. The losses at this point would therefore be higher than those measured in 50S2. Changing the diodes to HP 3091 types had introduced about 4dB additional loss which was clearly not acceptable. G4PKT had also changed diodes on the 1st IF board between the IF roofing filter and the narrow IF filters; this accounted for further losses."

"When all diodes were restored to the original BA482 type normal operation was restored - a task taking days to achieve. I realise that the original purpose of the exercise was to reduce 2nd order effects ascribed to the switching diodes. My existing test equipment introduces more 2nd order products than the diodes. Better isolation is required between the test oscillators and the hybrid combiner and I hope to follow this up soon."

"As a result of this exercise, I came to the following conclusions:"

1. Owners should consider carefully before attacking expensive transceivers. Only consider making modificatior if technically competent and equipped to measure the results. The actual circuit configuration should be considered to judge the likely effects of a modification. It may prove to induce high losses and will almost certainly effect filter termination impedance's required realignment. Some modern filters have fixed values and therefore performance on receive and transmit could be compromised.
2. The validity of the original articles is brought into doubt. If the author did not consider the effect of an extra 4dB of loss inserted before the first mixer, the resulting improvement in intermod performance credited to th use of PIN diodes may be a false assumption. Building a 4dB input attenuator is much cheaper than changing all those diodes!
3. Considering specifically the OMNI VI, rather than changing diodes, performance would probably be enhance by implementing better matching of the 1st mixer. The IF port has no diplexer and the buffer amplifier has only a 20dB return loss at 9MHz. The LO port is fed directly from the LO power amplifier without any attemp at matching. Better filtering at the RF signal input would reduce 2nd order effects.

G4HRY is particularly concerned by the unquestioning faith often put in published articles, including QST and RadCom. He urges others to follow his own philosophy and become professional sceptics!

In his three-part article, Dr Rohde noted that second-order IMD products change 2dB for every decibel of input-signal change, and appear at frequencies that result from the simple addition and subtraction of input-signal frequencies. His introductory notes on switching diodes were as follows:

"The receiver sections of amateur MF/HF transceivers generally use diode-switched front-end filtering. The switching diodes used have low junction capacitance and can typically handle medium DC levels (10 to 100mA). These characteristics are important because we want these diodes to contribute minimal loss when turned on and leak very little RF when turned off."

"The two-tone, third-order MD dynamic-range testing routinely done to amateur transceivers seems to point up no weakness in these switching diodes. In real life, however, a huge number of signals simultaneously appear at a transceiver's antenna connector. Periodically, their voltages all sum in phase producing, for short durations, enough voltage to change the bias of the diode at the input of the filter in use. This causes intermodulation distortion - generally ,second-order IMD. This is ironic for two reasons: First, this diode-generated IMD generates exactly the interference the filters switched by the diodes are supposed to prevent! Second, amateur radio equipment reviews have long let second-order front-end IMD go unmeasured because we have long assumed that our radios f rontend filtering reduces this IMD to a non problem. Later, I will present measurement results that prove that second-order IMD is a very real problem today. (The test jig used by WOIVJ is shown in Fig 2 with some of the results in Table 2 - G3VA)."

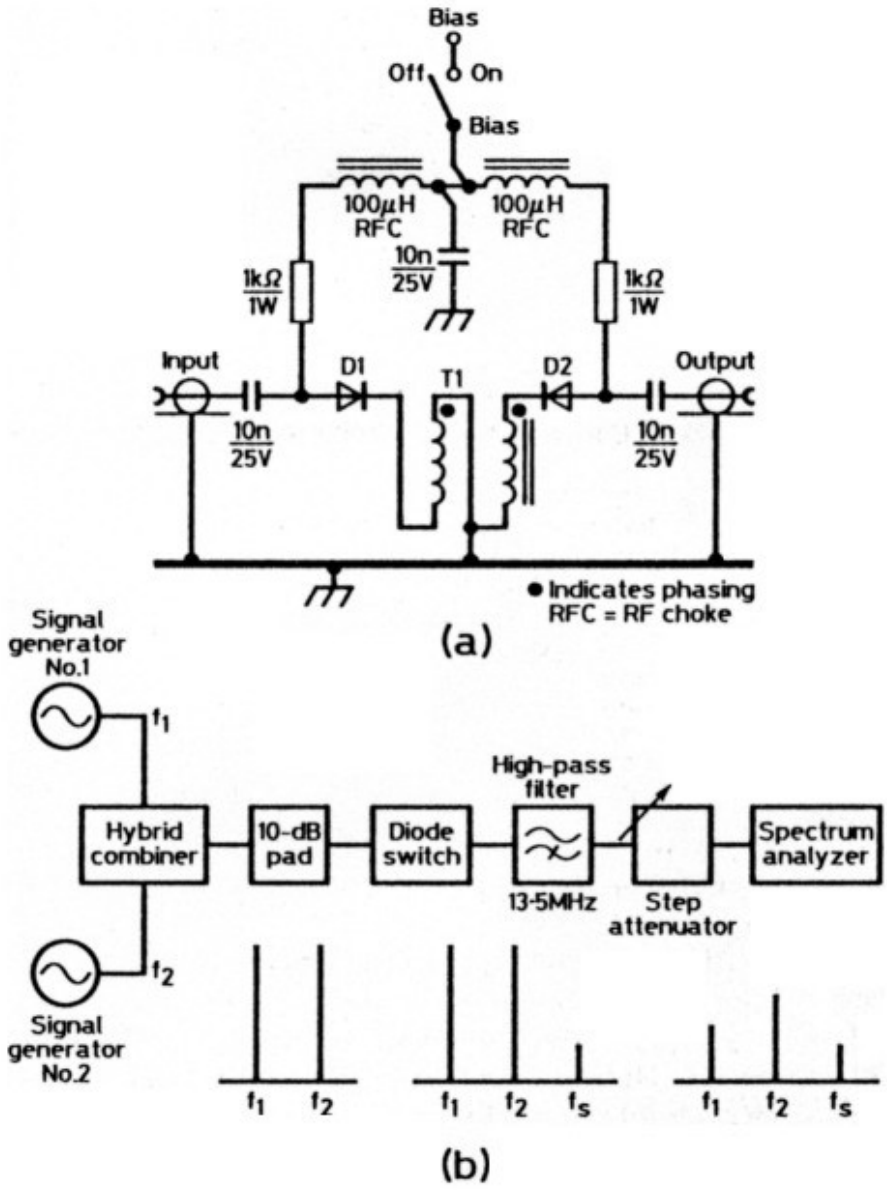

Fig 2: (a) The diode switch used by WOIVJ for his tests. D1 and D2, the diodes under test, included PN and PIN (power-rectifier and RF-specified) types. Capacitors are disc or monolithic ceramics. T1 consists of 11 bifiliar turns o Nr28 enamelled wire on an FT-37-43 ferrite toroidal form; the inductance of each winding is about 50uH. (b) Set up

for measuring the diode switch's second - and third-order intercept points.

Table 2(a): W0IVJ's Diode Switch insertion loss (dB) at 10MHz

Diode	Bias conditions per diode				
Type	Reverse	0mA	5mA	10mA	20mA
1N4153	75	75	2	1	0.5
MPN3700	70	55	0.1	0.1	0.1
BAR17	75	70	0.3	0.1	0.1
1N4007	35	20	0.1	0.1	0.1

Table 2(b): diode switch second-order intercept point (IP2) dBm

Diode	Bias conditions per diode				
Type	Reverse	0mA	5mA	10mA	20mA
1N4153	>80	>80	18	30	42
MPN3700	>80	60	66	70	72
BAR17	>80	>80	60	70	75
1N4007	>80	40	>80	>80	>80

Table 2(c):diode switch third-order intercept points (IP3), dBm

Diode	Bias conditions per diode				
Type	Reverse	0mA	5mA	10mA	20mA
1N4153	>50	>50	20	30	37
MPN3700	>50	47	>50	>50	>50
BAR17	>50	50	>50	>50	>50
1N4007	>50	35	>50	>50	>50

"The best way to avoid switching-diode IMD is to switch the filters with relays instead of diodes, and military and commercial gear generally take this approach. Relays are costly, however. A less expensive workaround that is acceptably good for amateur radio equipment is to use diodes - PIN diodes - designed for this application. The two best-known US manufacturers of PIN diodes for this type of low-frequency application are Hewlett-Packard and Alphas Industries. The best diode for the shortwave range is the HP 8052-3081..."

Harry Leeming, G3LLL, was also concerned at the idea of using RF PIN diodes. He writes: "It is all very well testing equipment when new, but how well do the modern Schottky (hot-carrier) diodes stand up in service? Take, for example, the F175. These have a reputation of being noisy on receive. Indeed, on many samples if you switch in the RF preamp, the noise comes up more than the signal. Check the dozen diodes around the input to the band pass filters and the Tx/Rx switching and up to half of them are likely to be found leaky. (They are ISS97 Schottky-barrier diodes)."

"Despite their being 'yesterday's technology' I replace these diodes with 1N4148 or similar. The receiver then becomes as good as new, and usually stays that way. I wonder if anyone can suggest modest-priced diodes that are better than the 1 N4148 and will stand up in service? Meanwhile, I am unable to detect any difference between a nev F1757 and one that has had 1 N4148s fitted".

My own feeling is that the experiences of both G4HRY and G3LLL highlight an increasingly serious problem involving modern technology. Without the most advanced (and expensive) laboratory test equipment, it is extremely difficult to evaluate fully the performance of equipment. With equipment which is new, or has been in service for some months, it is hard to assess how important these laboratory measurements are likely to prove in normal operational use on the amateur bands. In the case of HF receivers/transceivers, the 'old technology' of variable-capacitor tuned RF filtering with mechanical wavechange switching did have significant advantages over current broadband low-pass' or even sub-octave bandpass filtering. However, the 'old technology' was not without its own problems and costs.