G3SBI'S HIGH PERFORMANCE MIXER

LAST MONTH'S *TT* ITEM on G3SBI's investigation of N6NWP's 'High-dynamic-range MF/HF receiver front end' (*QST*, Feb 1993, pp23-28) revealed that he had subsequently developed an entirely new way of using an SD5000 DMOS quad-FET array that promised to provide even greater dynamic range, particularly on the higher HF bands. His new 'H-mode' configuration fulfils this promise and seems to open the way to a multiband HF receiver of superlative performance.

In presenting information on this new mixer configuration, it should be made clear that Colin Horrabin, G3SBI, is a professional scientist/electronic engineer at the Science and Engineering Research Council's Daresbury Laboratory which has supported his investigative work on the H-mode switched FET mixer and consequently holds intellectual title to the new mixer. This does not, of course, prevent readers from taking the development further or using the information presented in September or this current *TT* item.

G3SBI writes: "The previous information covered an investigation of all the component parts of a high-performance front-end including a note on the limitations of the crystal filter intercept point. Although the intercept point of the filters readily available on the UK amateur market appeared to limit the performance of a front end to some degree, this could be made compatible with high-performance mixers if no post-mixer amplifier was used in front of the filter and a quadrature hybrid network with two low-loss SSB filters immediately followed the mixer. The SD5000 DMOS FET mixer described in the September *TT*, followed basically accepted practice in commutation (switching) mixers and achieved a +50dBm input intercept point on 7MHz with the use of square-wave drive.

"However, as noted, it was not possible to achieve this performance on all amateur HF bands, including bands lower and higher in frequency than 7MHz. The results were improved on the lower frequency bands by altering the capacitive balance of the RF input transformer, but this had no significant effect on 14MHz and above. It was felt that a configuration for the mixer where the RF input signal was not in the gate source switch-on path would prevent modulation of the true gate-to-source local oscillator voltage by the RF input signal.

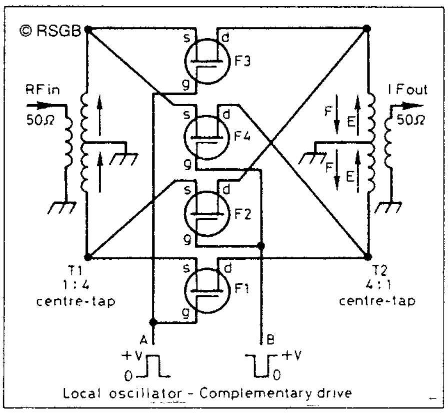

Fig 1: Conventional commutation mixer arrangement based on quad-FET array.

Pat Hawker's Technical Topics

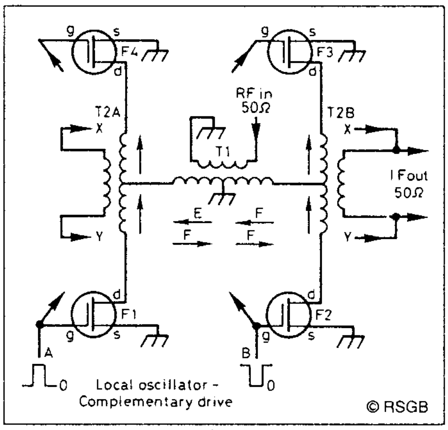

Fig 2: The new 'H-mode' commutation mixer.

"The performance of the new mixer is as follows: With an input RF test level of +11dBm (0.8V RMS two tones spaced at 2kHz or 20kHz); conversion loss 8dB; RF to IF isolation -68dB; LO to IF isolation -66dB. Input intercept points: 1.8 to 18MHz +53dBm; 21 to 28MHz +47dBm or better; 50MHz + 41dB. These results were achieved with a gate-to-source DC bias of +1.95V and -8V substrate bias, a square-wave local oscillator amplitude of 9V and an IF at 9MHz.

"**Fig 1** shows a conventional commutation ring mixer: if A is 'on', FETs F1 and F2 are 'on' and the direction of the RF signal across transformer T2 is given by the 'F' arrows. The main deficiency of this classic circuit is that as the RF input signal level increases, it has a significant effect on true gate-to-source voltage needed to switch the FET 'on' or keep it switched 'off'. Larger local oscillator amplitudes are then required, but linearity problems may still exist because of the difference in the FET 'on' resistance between negative and positive RF signal states.

"The alternative arrangement is shown in **Fig 2**. The shape of this diagram illustrates why the new mixer has been named 'H-mode'. Inputs A and B are complementary square wave inputs derived from the sine-wave local oscillator at twice the required frequency. If A is 'on' then FETs F1 and F3 are 'on' and the direction of the RF signal across T1 is given by the 'E' arrows. When B is 'on', FETs F2 and F4 are 'on' and the direction of the RF signal across T1 reverses (arrows 'F'). This is still the action of a commutation mixer, but now the source of each FET switch is grounded, so that the RF signal switched by the FET cannot modulate the gate source voltage.

"In this configuration the transformers are important: T1 is a Mini-Circuits type T4-1; T2 is two Mini-Circuits T4-1 transformers with their primaries connected in parallel. It is possible that a special five-windings transformer might give even better results, but so far the intercept points achieved with a home-made transformer have been unsatisfactory; it is probably a question of having the right ferrite material. However, the parallel-connected transformers give good balance and perform well.

"The practical test circuit is shown in **Fig 3**. It is constructed on an earthplane board and all transformers and ICs are mounted in turned pin DIL sockets. The printed circuit tracks connecting T1 to T2 and from T2 to the SD5000 are kept short and of 0.015-inch width to minimise capacitance to ground. Operation is as follows: The local oscillator is divided by two in frequency and squared by a 74AC74 advanced CMOS bistable similar to the SD5000 mixer described in the September *TT*. However the bistable is run from +10V instead of +9V and a cut-down RS Components ferrite bead is inserted over the ground pin of the 74AC74 to clean up the square wave.

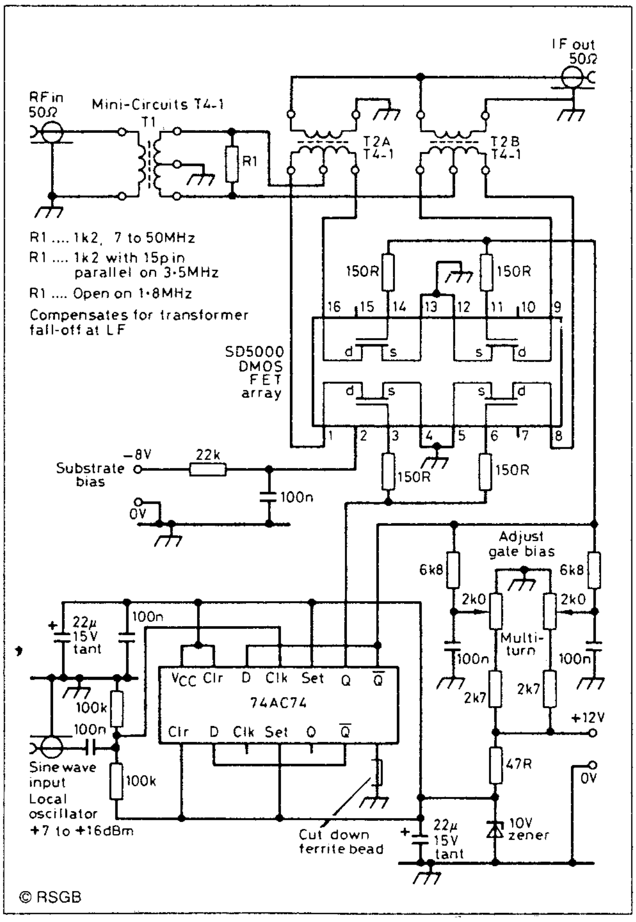

Fig 3: Test assembly for 'H-mode' mixer as investigated by G3SBI.

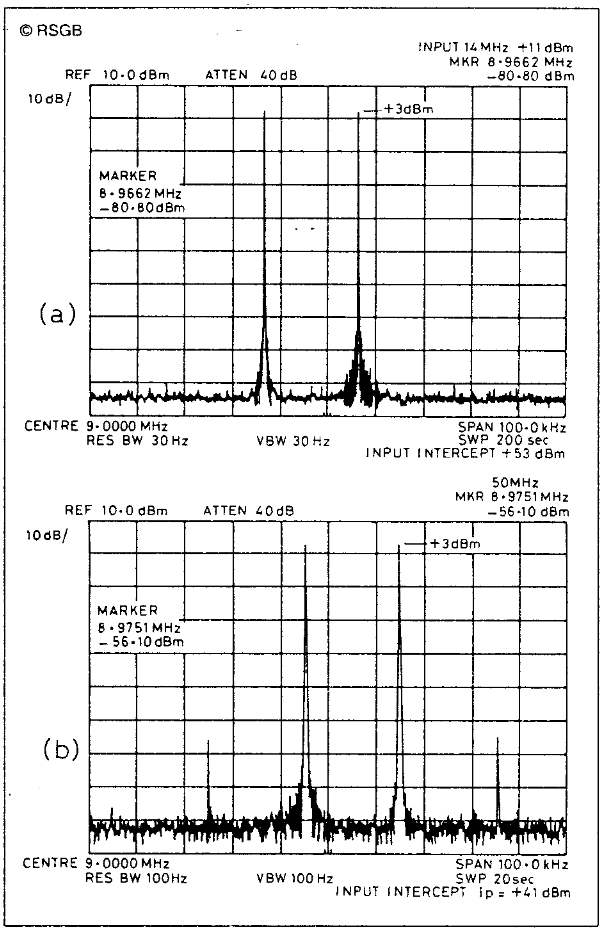

Fig 4: (a) 14MHz input intermodulation spectrum for output at 9MHz of the 'H-mode' mixer showing an input intercept of +53dBm. (b) 50MHz input spectrum showing an input intercept of +41dBm.

"The professional test equipment set up used to determine the H-mode mixer intercept points was the same as that noted in the September *TT* for the N6NWP-type mixers, including two Hewlett-Packard signal generators and spectrum analyser and a Rohde & Schwarz SMG signal generator to provide the LO sine wave input.

"The best method of setting the gate bias potentiometers proved to be as follows: One is set to the desired bias voltage for a specific test run, the other is then set by looking at the RF-to-IF path feed-through on the spectrum analyser at 14MHz, and adjusting the potentiometer for minimum IF feedthrough. The setting is quite sharp and ensures good mixer balance.

An RF test signal of 11dBm (0.8V RMS) was used for each test signal for the two-tone IMD tests. The results obtained were the same with 2kHz and 20kHz tone spacing [an indication of the purity of the LO source]. All the major HF amateur bands were used as RF sources in these tests and the spectrum analyser results recorded. The gate bias level chosen enabled an input level of +12dBm to be reached before the IMD increased sharply, breaking away from the normal 3:1 slope on a log plot.

"Spectrum plots for 14MHz and 50MHz are shown in **Fig 4**, indicating input intercept points on these bands of +53dBm and +41dBm respectively. These are excellent results but it is probable that even larger RF input signals might be handled with a lower gate voltage bias and a larger amplitude square wave injection. The use of the 74AC74 bistable as a square-wave generator is convenient, but the characteristic curves of the SD5000 suggest that a higher gate-to-source 'on' voltage would give a superior FET 'on' resistance for positive and negative drain-to-source signal voltages, possibly giving even better linearity, particularly on 50MHz."

G3SBI also concludes that an H-mode mixer does not have to be driven from a square-wave drive and suggests that it is likely that good results could be obtained with transformer-driven sine waves provided the injection was via capacitors so that the bias pots could still be used. Similarly he believes there is no reason why such a mixer should not be used in an up-conversion arrangement (rather than the 9MHz IF used with both his N6NWP-type and H-mode test mixers) as employed today in most factory-built receivers. The same approach could probably be applied at VHF/UHF with resonant-lines and GaAs FETs as switches. He is convinced that his work proves that the H-mode FET switching mixer is capable of extremely good intermodulation performance at HF with a 9MHz IF and merits further investigation for other applications. Development of the H-mode mixer has been a sideline to his professional work at SERC and it is unlikely that he will take its development further. However, he feels he has enough information to design a complete high-performance HF receiver, after first building and testing the necessary antenna input bandpass filters to ensure that they have intercept points in the +60dBm region.

Some initial tests by G3SBI with a simple two-crystal 9MHz ladder filter suggests that, as forecast in the September *TT*, this approach is likely to overcome completely the intercept limitations of most available lattice-type crystal filters.

THOSE REFLECTOMETER DIODES, IPS & HARMONICS

SEVERAL READERS HAVE pointed out that G3RZP's investigation into 'SWR bridges and Harmonics' (*TT*, August) leaves some unanswered questions. For example, when the antenna is not ideally matched, so that there will be reverse current flowing through the bridge diodes, a by-no-means unusual situation. Then, as Dennis Lisney, G3MNO, points out, there is the possible effect of the SWR-bridge diodes on incoming signals. He writes: "A few years ago I switched on my FT301 on 3.5MHz to find the band apparently full of 'rubbish', seemingly broadcast-based. This turned out to be generated by a non-linear Belling-type coax connector. A gentle wipe with wire wool provided a cure for another year or so. But some time later I changed the ATU for a pi-network to find the problem reappearing. The 'cure' this time was to remove the reflectometer after tuning up.

"Unfortunately, this does work with the FT290 and HX-240 transverter. The transverter seems to have a hard-wired protection reflector built-in. In my case, the problem seems to be connected with the very strong signals on 1.6MHz from the Capital Radio MF transmitter only a few miles away. This provides some 1V into 50Ω when my [low-pass pi-network] network is set to 3.5MHz. I have ducked the problem by using a link-coupled ATU of more 'classical form' (I have a preference for ATUs which isolate the antenna-earth from the mains-earth as experience suggests that this reduces interference from TV receivers etc). I have tried a number of reflectometers of several types. With a low-pass, pi-network ATU, I just cannot leave any in circuit and receive on 3.5MHz – on higher bands no problem – although I could not detect any meter deflection in either forward or reflected positions.

"There is a basic problem with reflectometers and ATUs in that one tends to think of them as working at the chosen frequencies, not the out-of-band frequencies!"

QUICKIE TRANSISTOR CHECKER

MANY YEARS AGO, *TT* described the ZL2AMJ Kwik-Sorta Mk 2 as a simple test set for bipolar transistors and diodes. It can sort out good from bad devices, identify lead connections and determine whether a transistor is a p-n-p or n-p-n device (details can still be found in *ART7* pp363-364).

A rather difference approach is described by Brian J Field, VK6BQN (*Amateur Radio*, August 1993, p26): **Fig 5**. He writes: "Almost all parts can be found in the junk-box and none is critical. The principle is that the transistor acts as an oscillator using the centre-tapped primary of a low-voltage [mains] transformer. The secondary (240V winding) drives a meter to indicate oscillation. If the transistor is a dud nothing happens and the meter doesn't move."

VK6BQN points out that some versions use a NE51 neon bulb instead of a meter, but the 1mA FSD meter is more sensitive since the NE51 requires about 60V to strike. He adds: "The transformer I used was 10-0-10V but 6V or 12V either side of centre tap should work. The only thing is to make sure there is something on the 240V winding that can be

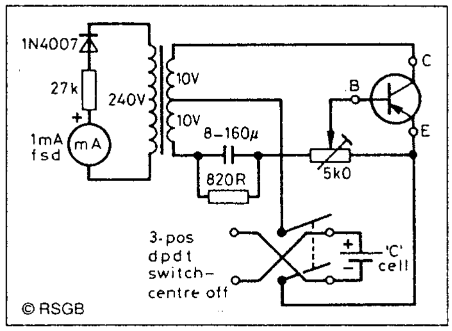

Fig 5: VK6BQN's 'Quickie Transistor Checker' (Amateur Radio).