Wolfgang Schneider, DJ8ES

2-Tone Generator For 145Mhz

An RF amplifier stage is not only classified by amplification, which is as high as possible, and thus by its maximum output. What is frequently not taken into account, but is decisive for the signal quality, is the inter-modulation performance.

In practice, because of the gain characteristic, which is not completely linear, RF amplifiers are bound to produce distortion. A standard method for measuring this inter-modulation, e.g. in SSB amplifiers, is the 2-tone measurement. TV engineering uses a 3-tone measuring procedure!

1.
General

In order to measure the inter-modulation behaviour of an amplifier stage, two signals of equal strength with frequencies f1 and f2 are applied to the input of this stage. The amplifier produces a spectrum of inter-modulation products from these signals. Particularly critical in practice are the third order (2f1-f2; 2f2-f1) and of the fifth order (3f1-2f2; 3f2-2f1).

Fig. 2 gives a graphical representation of the position of these inter-modulation products.

The objective, e.g. in SSB amplifiers, is to ensure that the third-order inter-modulation products are below 40dB in relation to the pure tone. Considerably tighter values apply to pre-stages and mixers. Should these quality criteria not be taken into account in design of an SSB transmitter, it leads to poor modulation quality and a broad signal. For receiver pre-stages, this lack of quality is clearly shown by the so-called “plug effect”.

To be able to measure the inter-modulation products, the 2-tone generator must itself produce a high-quality signal.

The equipment described here completely fulfils this requirement (Fig. 3). The output level is +10dBm (10mW) for each pure tone.

The selection of this signal level represents a compromise between acceptable cost and versatility. Thus the 2-tone generator can be used in the same way for measurements on pre-amplifiers and transmitting amplifiers. Should a higher output level be required, then a suitable power amplifier can be used with the 2-tone generator for 145MHz. OM Carsten Vieland (DJ4GC) has already tackled this subject some years ago in [5].

The two frequencies, f1 = 144.850MHz and f2 = 145.150MHz, permit both the measurement of the third-order and fifth-

Fig. 1: 2-tone generator for the 2m band, ready for operation in a housing.

order inter-modulation products using a spectrum analyser and the use of receiver to measure levels. All frequencies of interest lie within the 2m band.

2.
Circuit Description For Quartz Oscillator

The quartz oscillator using a U310 FET (T1) has a circuit which has been well-tried over the years. It has developed into a standard in the VHF range and beyond as an oscillator for microwave applications.

What is new here is the additional low-pass filter in the power supply. The voltage regulator noise is suppressed by an RC network, consisting of an R3/C19, after the 78L09 linear regulator (IC1).

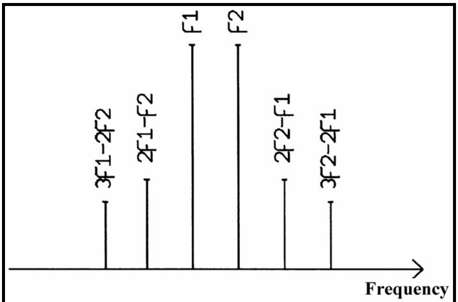

Fig. 2: Symbolic representation of a 2-tone signal with third-order and fifth-order inter-modulation products.

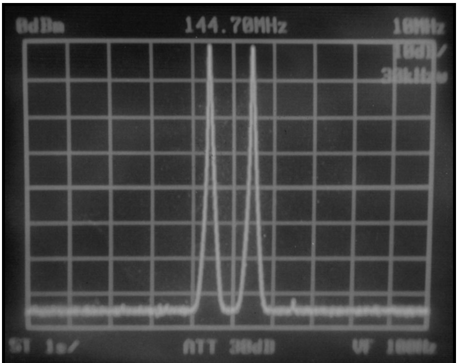

Fig. 3: A screen photo of the output spectrum allows us to recognise the high spectral purity of the 2-tone signal.

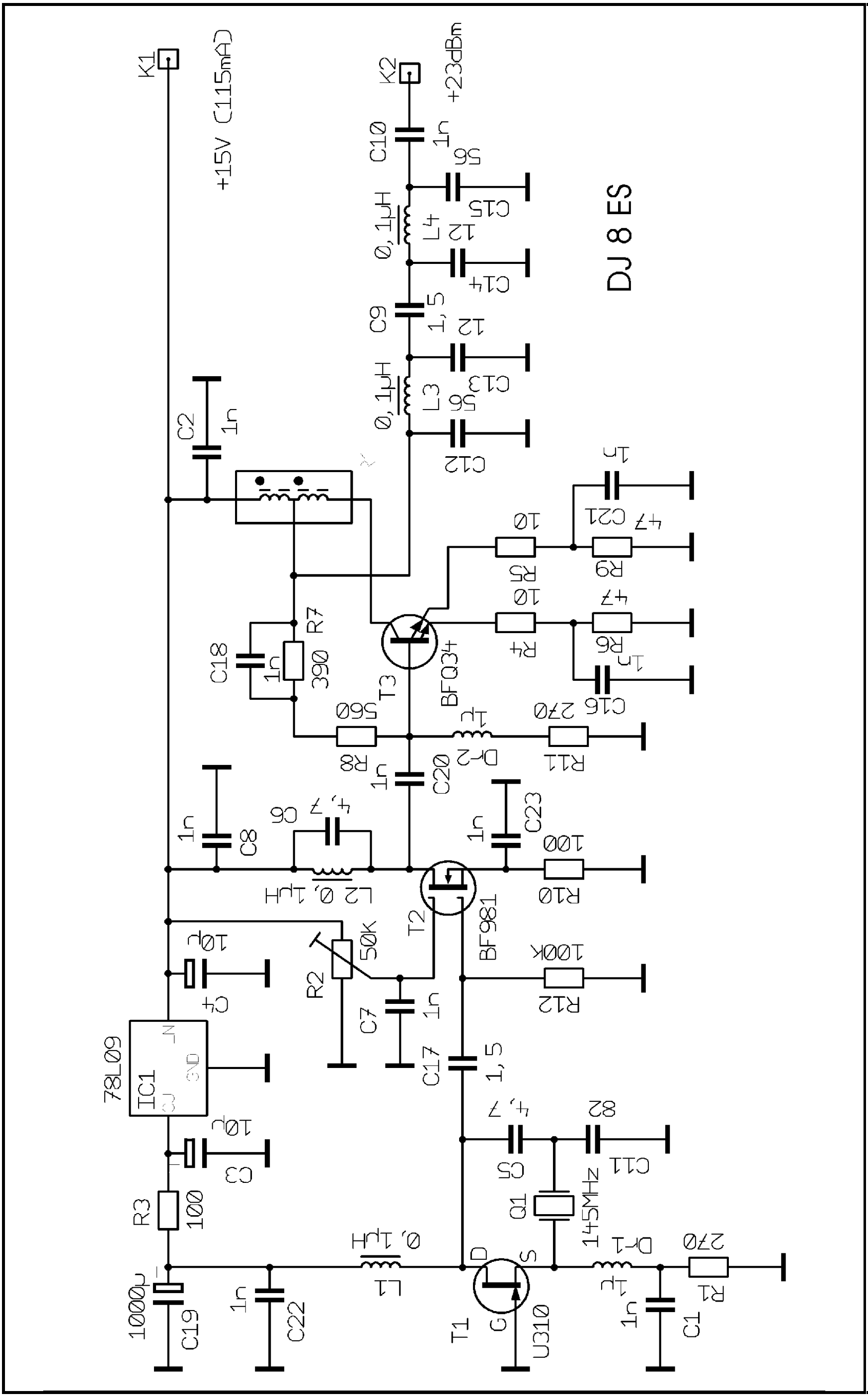

Fig 4 : Circuit diagram of 145MHz oscillator.

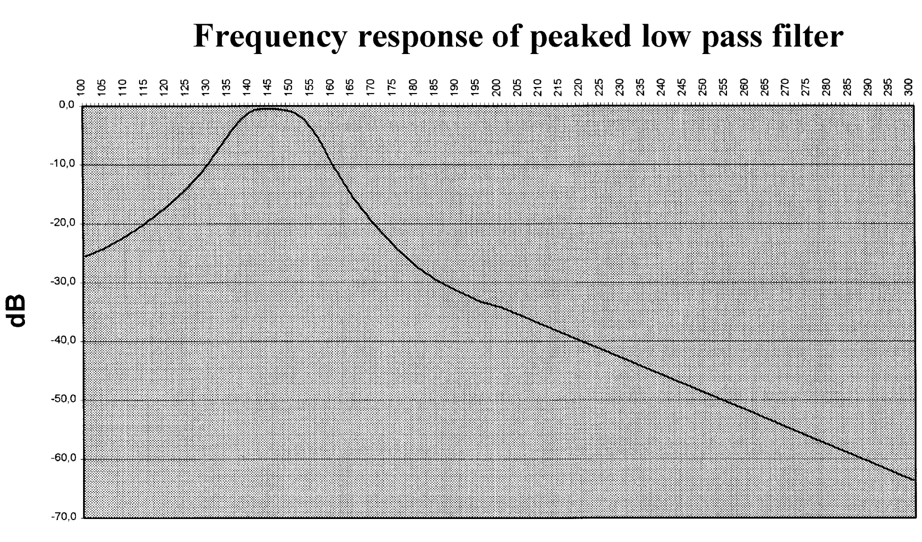

Fig 5 : Frequency response of the output filter in the oscillator (peaked low pass for 145MHz).

This has a direct influenced the quality of the quartz oscillator circuit.

The subsequent amplifier stage using a BF981 dual-gate MOSFET (T2), raises the oscillator signal to a maximum of +7dBm (5mW). The amplification of this stage can be adjusted over a wide range, using the 50kΩ trimmer.

The resonant circuit in the drain (L2/C6) is very broad in 50Ω technology, due to the high load presented by the following amplifier.

The final amplifier using a BFQ34 transistor (T3), increases the output to a maximum of +24dBm (250mW). The input and output impedance of the amplifier 50Ω. The current consumption for this stage is approximately 80mA (±15%), depending on the output, adjusted using the trimmer.

The low-pass filter at the output of the oscillator has a decisive influence on the spectral purity of the output signal at 145MHz. The insertion loss of the filter is approximately 1.3dB. The first harmonic at 290MHz is suppressed by more than 60dB. Fig. 5 shows the frequency response of the low-pass filter.

The output signal of the oscillator at 145MHz was investigated in greater detail by an Advantest R4131 spectrum analyser at an output of + 23dBm (200mW). No harmonic or spurious outputs were detectable with the measurement rig used. The level range which can be detected exceeded 80dBc.

2.1. Quartz oscillator parts list (for each individual oscillator assembly!)

T1	U310, transistor
T2	BF981, transistor
T3	BFQ34, transistor
IC1	78L09, voltage regulator
L1-L4	BV5061 Neosid 0.1µH ready-made coil
Q1	145MHz quartz, HC-18/U, series, 7th overtone (e.g. 144.850MHz and 145.150MHz for the 2nd oscillator)
TR1	Bifilar transformer, 2 x 7 turns

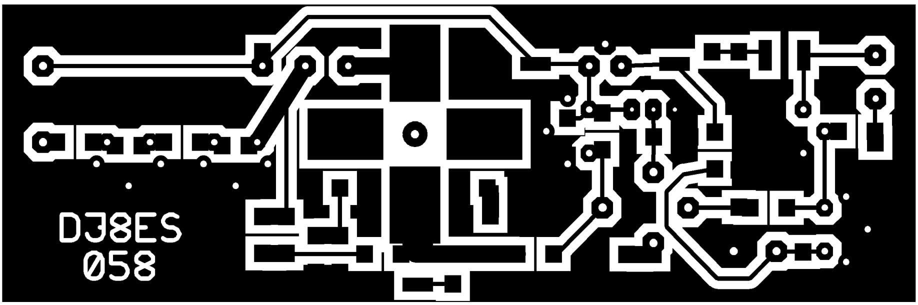

Fig 6 : PCB layout for 145MHz oscillator (not to scale).

	on ferrite core
R2	50kΩ spindle trimmer, 64 W model
C19	1,000µF electrolytic capacitor, 16V, radial
C3,C4	10µF electrolytic capacitor, SMD, 1812 model
Dr1,Dr2	1µH choke, SMD, 1812 model
1 x	DF-C 1nF, solderable
1 x	SMA flanged bush
1 x	WB housing, 37mm x 111mm x 30m.
1 x	printed circuit board DJ8ES 058

All other components in SMD 1206:

C1, 2, 7, 8, 10, 16, 18, 20-23 1nF

C5,6	4.7pF
C9	1.5pF
C11	82pF
C12,15	56pF
C13,14	12pF
C17	1.5pF
R1,11	270Ω
R3,10	100Ω
R4,5	10Ω
R6,9	47Ω
R7	390Ω
R8	560Ω
R12	100kΩ

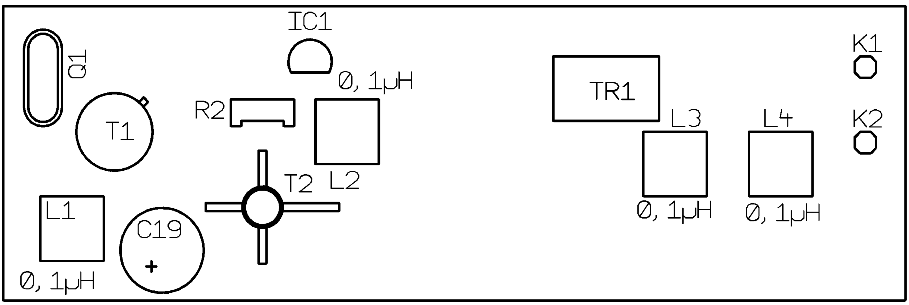

Fig 7 : Component layout for 145MHz oscillator (top side).

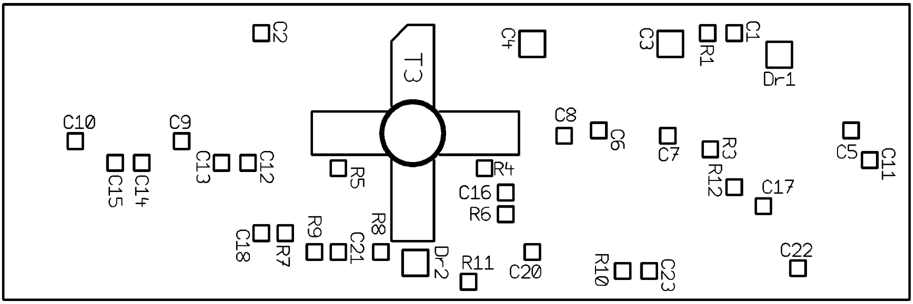

Fig 8 : SMD component layout for 145MHz oscillator (foil side).

2.2. Quartz oscillator assembly instructions

The quartz oscillator circuit for 145MHz is built on a 34mm x 108mm epoxy printed circuit board, copper-coated on both sides (Fig. 6). It fits into a commercially available 37mm x 111mm tinplate housing 30 mm high.

For the 2-tone generator, two oscillator assemblies are required with identical components. The only difference is the quartz crystal.

First drill the board with a 0.8 or 1mm drill, and then all holes for connections can been countersunk with a 3mm drill (N.B.: the copper remains on the connections to earth, e.g. the filter pots are soldered on both sides!). The SMA flanged bush and the feedthrough capacitor are fitted first. The board is inserted into the housing and sits comparatively low in the housing. The earth surfaces are soldered round both sides to the tinplate housing. The maximum fitting height is determined by the 1,000µF electrolytic capacitor.

2.3. Putting the quartz oscillator into action

Once the boards for the two quartz oscillators have been fully assembled, they should first checked for any possible placement faults. When all components are correctly inserted and soldered, the

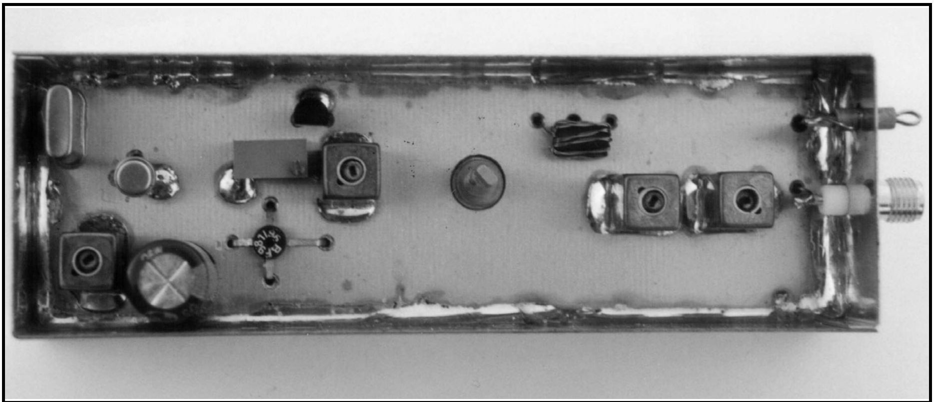

Fig 9 : Ready to operate 145MHz oscillator assembly.

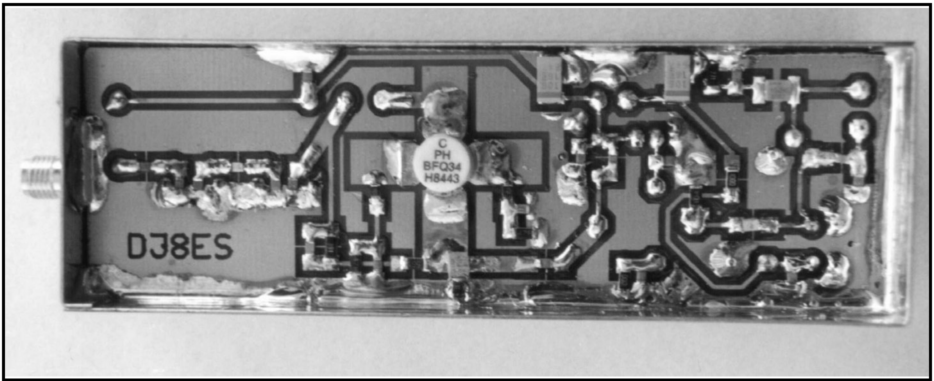

Fig 10 : Ready to operate 145MHz oscillator assembly showing SMD components on foil side of PCB.

first oscillator for 145MHz can be put into operation.

The supply voltage is +15V, with a current of approximately 100mA. The current varies by approximately 15%, depending on the output selected. This level can be adjusted between + 3dBm (2mW) and +24dBm (250mW) using the 50kΩ trimmer at G2 of the BF981 (T2). Pre-setting the output to +20dBm (100mW) is advantageous for subsequent use in the finished two-tone generator for 145MHz.

First the quartz oscillator (T1, U310) is put into operation. When the core is carefully rotated in the coil (0.1 µH), the circuit should start to oscillate. The core is fixed somewhat below the point for maximum output so that the oscillator starts reliably.

To measure the power, a suitable milli-watt meter can be connected at the output. Be careful, the power level is a maximum of 250mW. The low-pass filter at the output is then to be adjusted to the maximum output level by alternately trimming coils L3 and L4. The fine tuning of coil L2 completes the calibration procedure.

3. Combiner circuit description

The combiner adds the signals, f1 and f2, of the two quartz oscillators (Fig. 11). The inputs are connected using a 3dB attenuator for better de-coupling. The bifilar transformer, TR1, combines the two input signals.

The circuit contains no active components, which would unnecessarily degrade the signal quality.

Each signal branch contributes (fairly precisely) 10dB to the signal loss, 3dB is due to the attenuator and 7dB to the actual combiner. For a drive output of 2 x 100mW (+20dBm), there is thus a 2-tone signal at the output of the assembly with a total output of 20mW (+13dBm).

3.1. Combiner parts list

R1-3	50Ω, SMD, model 1206
R4,6,7,9	300Ω, SMD, model 1206
R5,R8	18Ω, SMD, model 1206
TR1	Transformer, 7 turns, 0.2mm enamelled copper wire, bifilar wound on ferrite bead

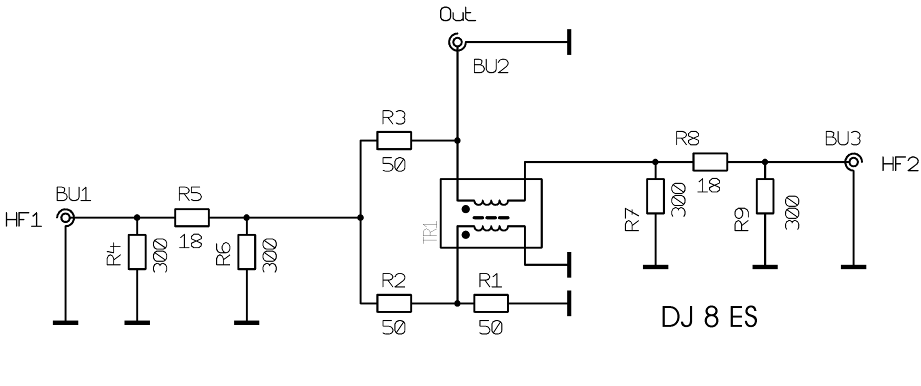

Fig 11 : Circuit diagram of combiner for two frequencies in 2m band.

3 x SMA flanged bush

1 x tinplate housing, 37mm x 55mm x 30mm

1 x printed circuit board DJ8ES 059

3.2. Combiner assembly instructions

The combiner assembly is constructed on a 34mm x 54mm epoxy printed circuit board, copper-coated on both sides (Fig. 12). It fits into a commercially available 37mm x 55.5mm x 30mm tinplate housing.

The printed circuit board is assembled from the foil side only, 0.8mm holes are first drilled for the transformer, TR1. Apart from the connection to earth, these holes are countersunk on the earth surface using a 3mm drill. The connection to earth is soldered on both sides.

Before the assembly in accordance with the assembly drawing in Fig. 13, the printed circuit board is inserted into the tinplate housing with the SMA sockets already fitted. The earth surfaces should be soldered to the housing rim on both sides.

Anyone who cannot afford the cost of special 50Ω resistors can use100Ω resistors in parallel (piggyback). For reasons of symmetry, these resistors should be measured as precisely as possible in advance!

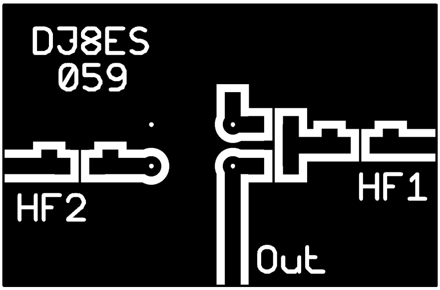

Fig 12 : PCB layout for combiner (not to scale).

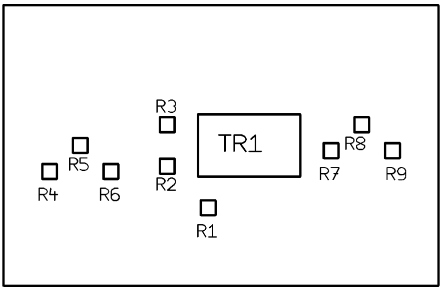

Fig 13 : Component layout for the combiner, all components are mounted on the foil side.

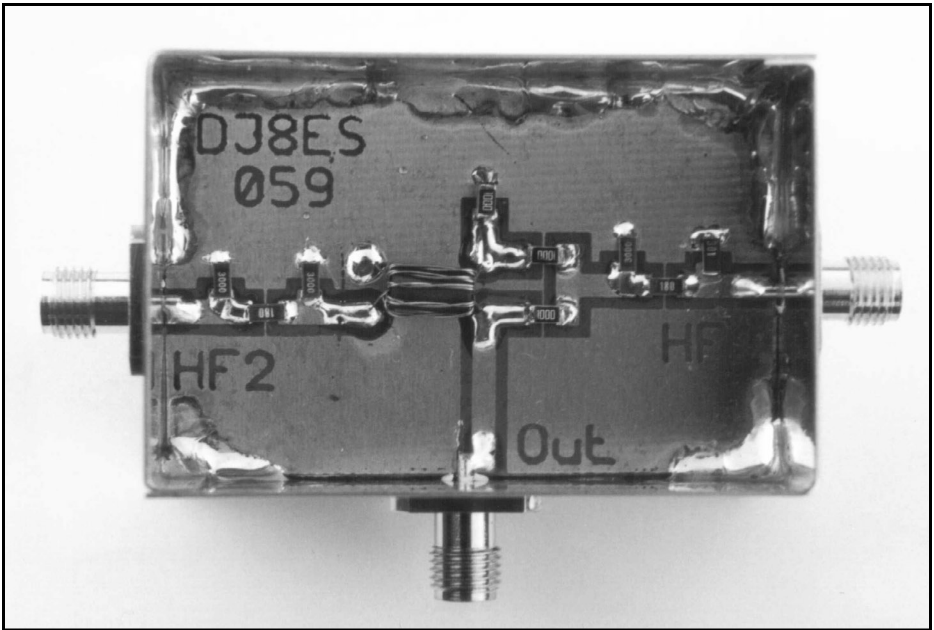

Fig 14 : Combiner for the 145MHz 2-tone generator, assembled and ready to operate.

4.

2 x 15 v power supply

Each of the two crystal oscillators is powered by its own supply voltage (15V, 100mA). The two linear regulators (IC1, IC2) keep the voltage stable at the required value. In other respects, the circuit for the power supply (2 x 15V) in Fig. 15 is self-explanatory.

The assembly is built on a 100mm x 75mm epoxy printed circuit board, copper-coated on one side (Fig. 16). During assembly set-up, particular attention should be paid to the 230V connection side and the fuse and the transformer, see Fig 17. The safety regulations required are described in DIN EN 60065 (VDE 0860) for audio, video and similar electronic apparatus (October, 1998 version).

4.1. Parts list

TR1	Transformer, 18V, 555mA, type EI48/16.8 10 VA
BR1	B40C1500, bridge rectifier
IC1,IC2	7815, 15V voltage regulator
C1	1,000µF electrolytic capacitor, radial, RM, 7.5mm.
C2,C3	47µF electrolytic capacitor, radial, RM 5mm.
C4,C5	100nF, ceramic, RM 2.5mm.
F1	100mA fine-wire fuse, delayed action, D = 5mm. x 20mm.
2 x	profile heat sinks SK 104 38.1 STS, can be soldered in
1 x	fuse holder for printed circuit board mounting
5 x	1mm soldering studs
1 x	printed circuit board DJ8ES 060

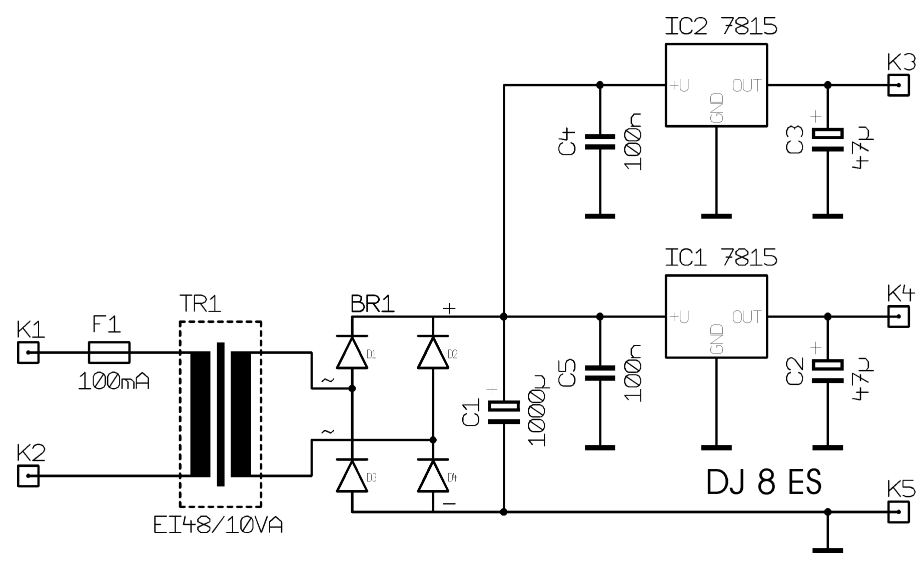

Fig 15 : Circuit diagram for 2 x 15V power supply.

5.
Putting into operation

Once all assemblies have been constructed ready for operation and positioned in a suitable housing, the two-tone generator can be put into operation as a whole for the first time.

The two oscillator assemblies can be individually connected in the specimen apparatus (Fig. 18). The RF level for each oscillator is individually set at +10dBm (10mW), measured at the output socket of the apparatus. If both

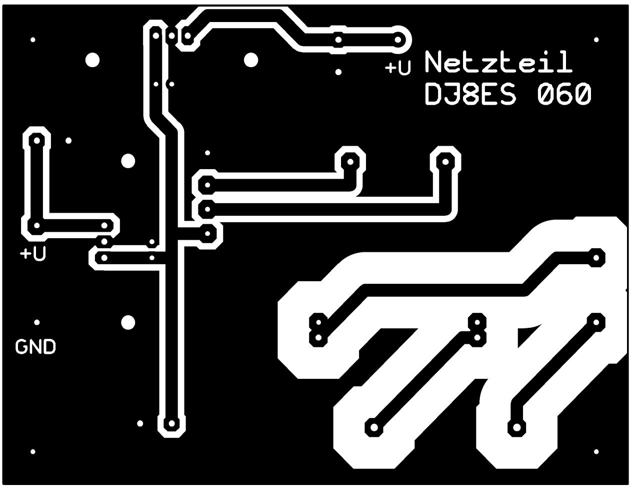

Fig 16 : PCB layout for power supply (not to scale).

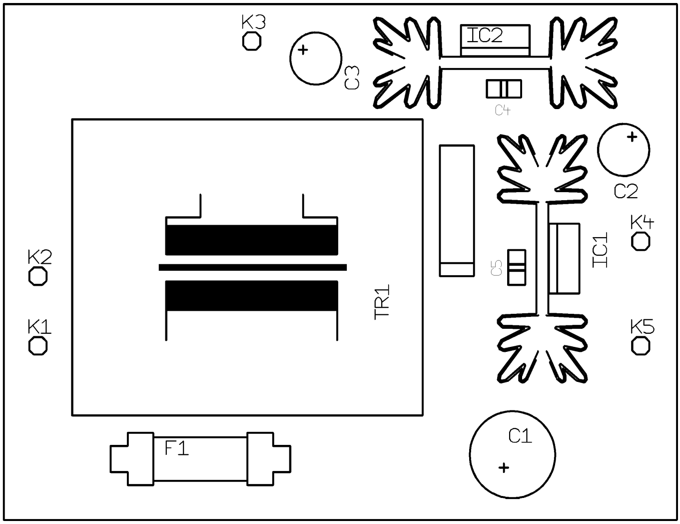

Fig 17 : Component layout for power supply.

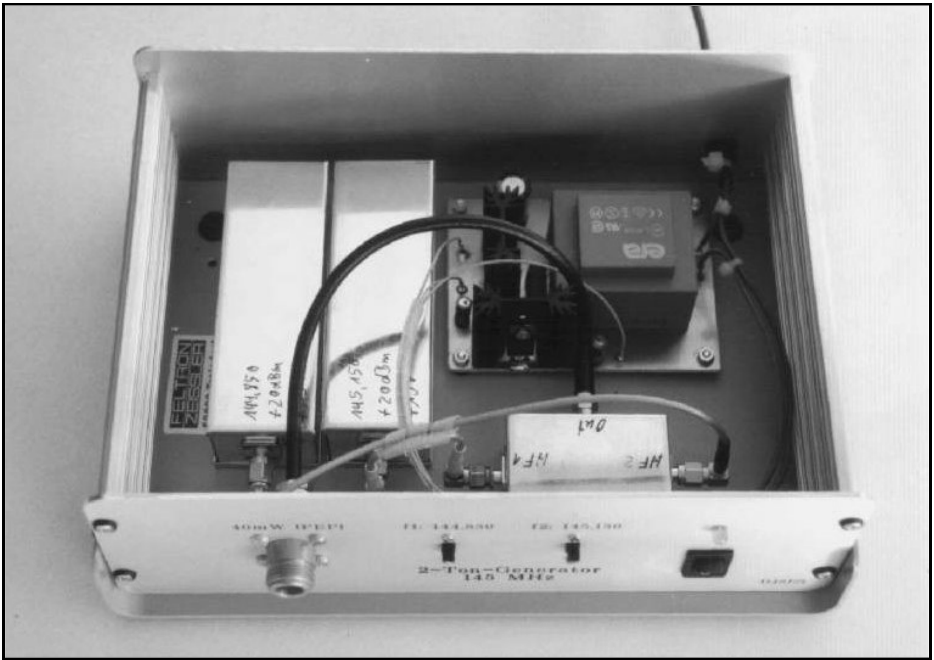

Fig. 18 : View into open specimen apparatus. The two oscillator assemblies for 144.950 MHz and 145.150 MHz are mounted in the left-hand half. The combiner sits directly behind the front panel and the power supply assembly is some way behind that.

assemblies are switched on, the total signal measures +13dBm (20mW) or 40mW PEP.

The two-tone signal is now visible at 145MHz on a connected spectrum analyser. Fig. 3 shows the good signal quality of this generator. It should be taken into account here that most spectrum analysers are already extremely over-modulated at such an output level and produce inter-modulation products themselves! Such signals can be measured only using a series-connected 20dB or 30dB attenuator.

6.

Literary references

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[3] Philips Semiconductors RF transmitting transistor and power amplifier fundamentals Philips Semiconductors 1998

[4] Plessey Semiconductors Publication no. AN156 Issue No. 2.0 Plessey Semiconductors Sep. 1993

[5] Carsten Vieland, DJ 4 GC Broadband, low inter-modulation, low-output amplifier from 3 to 600MHz CQDL 11/88 Pp. 680-682