

GB3MHS Goes on the Air

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Abstract

At the 42nd Weinheim Convention a paper was presented describing the plans for new 2.3 and 24 GHz beacons at Martlesham, in the UK. This paper describes the design, construction and installation of the 2.3 GHz beacon, GB3MHS.

Introduction

In the paper presented last year, a design for a 2.3GHz beacon, with an ERP of +14 dBW was described [1]. This design was used as the basis of the application for the beacon licence. This paper presents the actual design that has been implemented to achieve the design parameters specified in the application, in the most appropriate and economic manner.

It also demonstrates the construction and installation of the hardware, in preparation for bringing the beacon on to the air. This paper is based on a paper presented in 1998 [2], but updates significant changes that have taken place, particularly in the design and implementation of the Antenna Unit.

Differences From the Original Design

In the original design it was planned to use an oscillator multiplier strip according to the G4DDK/004 design, and a 1W PA to the DB6NT design. This concept has been modified by the generous donation of the former ON4RUG beacon hardware by Freddie, ON6UG.

This hardware consists of a 'stand-alone' combined keyer, oscillator, multiplier, amplifier and antenna mounted in a 'radome' assembly. The entire unit is mounted on the supporting tower and only requires to be supplied with DC power at about 15V.

As donated to us, the assembly needed some modifications to meet our requirements, but it also provided many of the basic elements needed, already constructed. The focus of this paper is therefore the modifications and work required to bring about the realisation of our beacon.

The Construction of the ON4RUG Beacon

To introduce the modifications required, a brief description of the donated hardware is required.

The entire beacon assembly sits inside a 100mm diameter plastic tube, sealed at the top, acting as the radome. Inside there are two slotted transmission line antennas, giving a total of 16 dBi gain, and a bi-directional horizontally polarised radiation pattern with a half power beamwidth of about 135° on each lobe.

Mounted centrally in the tube, between the two antennas was the keyer/oscillator/multiplier and amplifier. The keyer was based on the G4FRE EPROM design [3], and the RF strip on the DD9DU design, generating 2320 MHz from a 96MHz range crystal. A 1W amplifier using a CLY5 and CLY10 had been integrated into the multiplier unit. DC power was supplied via a coaxial cable feed, through an N type connector, accessible through a hole in the side of the plastic radome tube.

The GB3MHS Design

A compromise design was developed, adhering where possible to the original application design, but making maximum use of the existing hardware. This design is shown as a functional block diagram in Fig 1. It is 'compatible' with the other beacons run by the Martlesham Radio Society, in that there is a rack mounted unit housing power supplies, keying and frequency generation, and a masthead unit containing frequency multipliers, amplifiers and the antenna system.

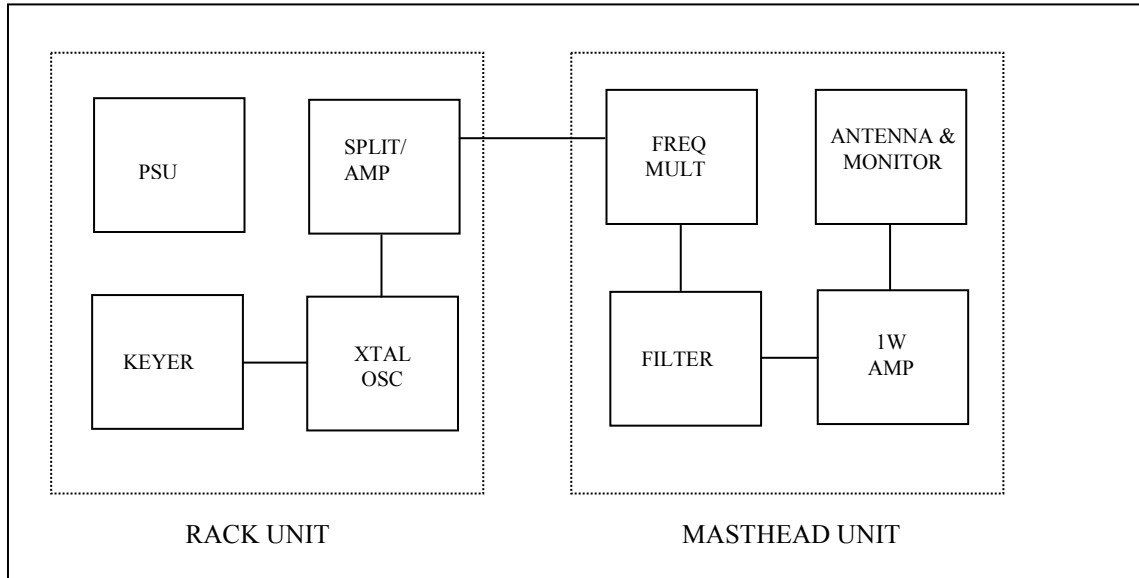


Fig 1 GB3MHS Schematic Diagram

GB3MHS Rack Unit

Fig 2 details the functions in the rack unit:

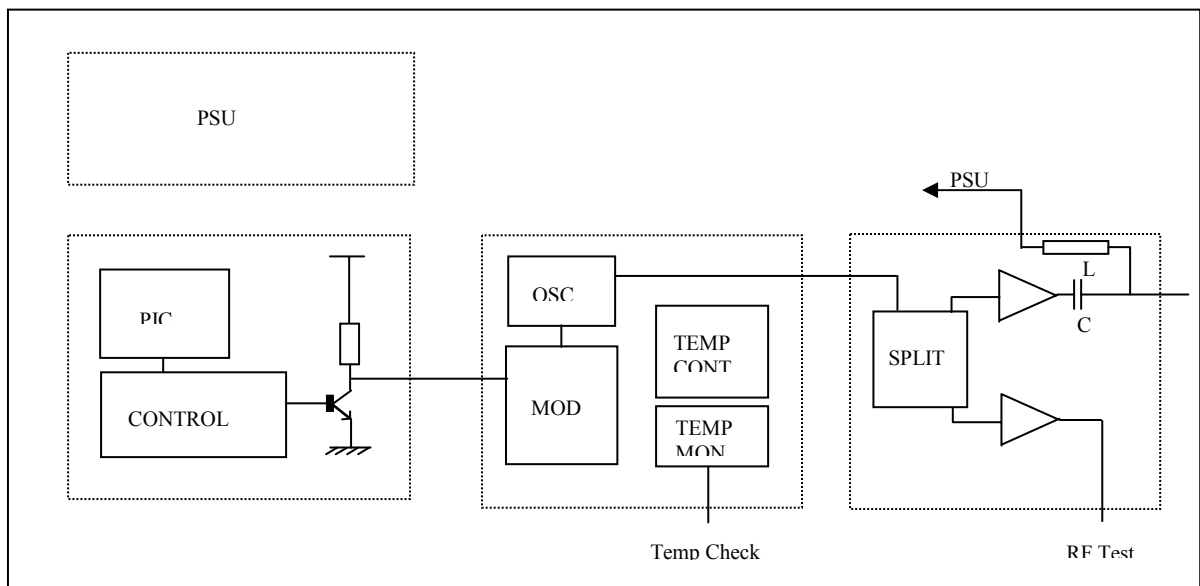


Fig 2 GB3MHS Rack Unit Functions

This is a 1U high unit, housing a switching mode PSU, the master oscillator, keyer and a splitter amplifier stage. The PSU provides power both for the internal circuitry, and for the masthead unit via power feeding over the coaxial cable carrying the RF signal. AC mains is supplied via an IEC inlet connector, and is switched by a keyswitch on the front panel – to allow convenient and rapid closedown in the event of such a request. The remaining three modules are explained in more detail below.

The keyer circuit – shown in Fig 3 – is based around a 12C508 8 pin PIC embedded controller. The code was developed by G4FRE/WW2R [4], and is a natural development of his earlier EPROM design. The keying sequence for the beacon is based on a pattern of four cycles. On the first cycle it transmits ‘GB3MHS JO02pb 2320.830MHz’, whilst on the remaining three cycles just the callsign is sent. In between each cycle a continuous mark of approximately 15 seconds duration is transmitted.

The output from the keyer is used to drive the base of a keying transistor for the modulator. The drive is taken through a front panel non-latching switch allowing either continuous mark or space to be manually selected for test and measurement purposes. A modulation adjustment is also provided within the keyer enclosure and the anti-phase output of the keyer chip is used directly to drive a front panel keying indicator LED.

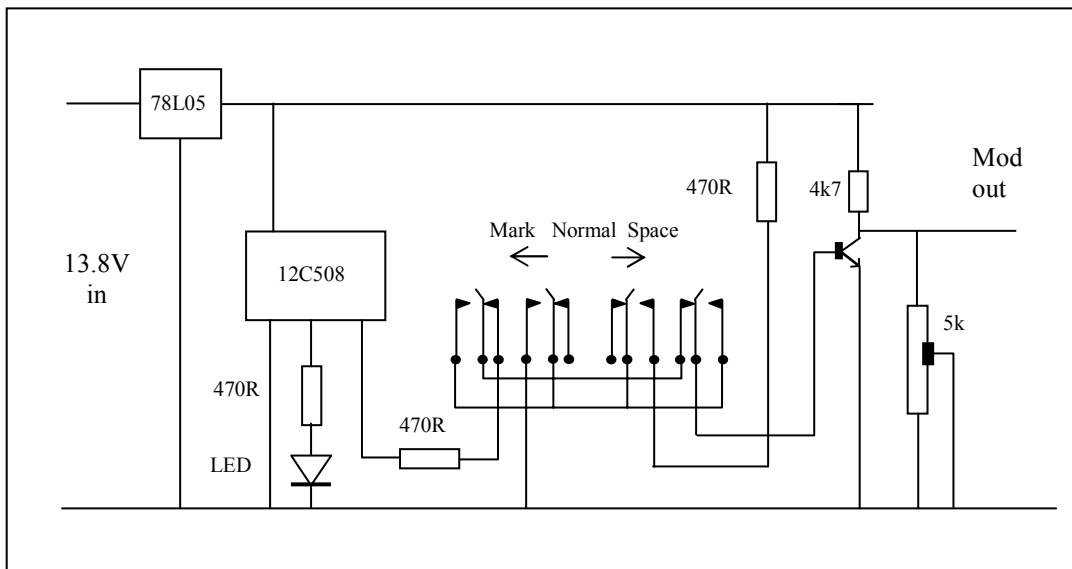


Fig 3 GB3MHS Keying Circuit

The master oscillator is an adaptation of the DF9LN temperature controlled design. The modifications are in the addition of a modulator stage in the oscillator part of the circuit, and the attaching of an LM334Z to the heatsink, to allow external monitoring of the oscillator temperature, using a multimeter. This circuit gives 10mV DC output per °K – thus for 50°C, the DC output is approximately 3.24V.

Fig 4 shows the diagram of the oscillator circuit with the modulator components indicated, and Fig 5 shows the temperature monitoring modifications. The oscillator runs at 96.70125 MHz, and is set to operate at a temperature of 50°C – it draws approximately 50mA under equilibrium conditions.

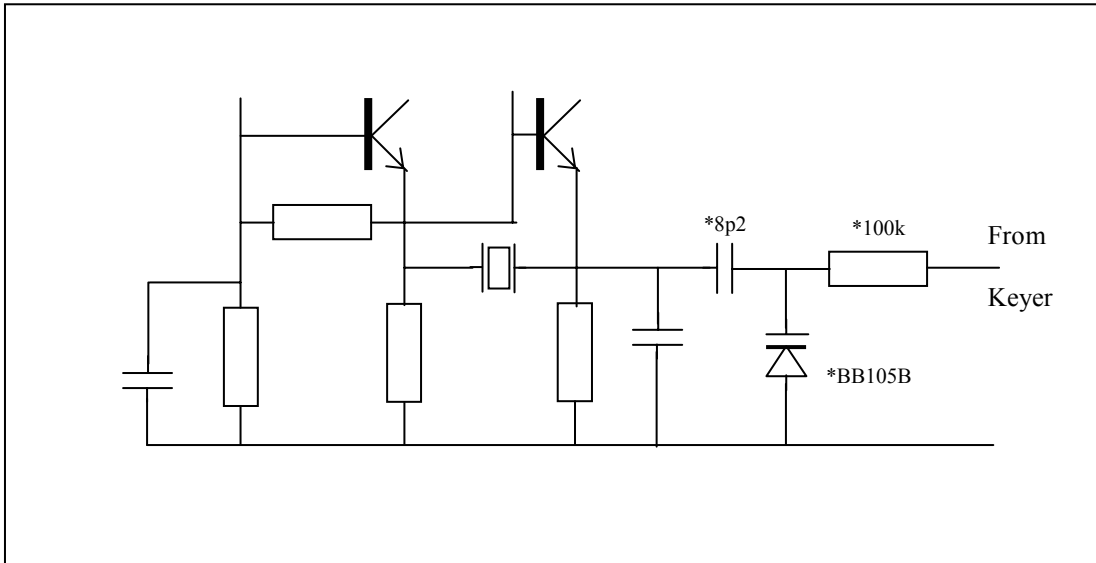


Fig 4 Partial Circuit of DF9LN Oscillator, showing added components (*)

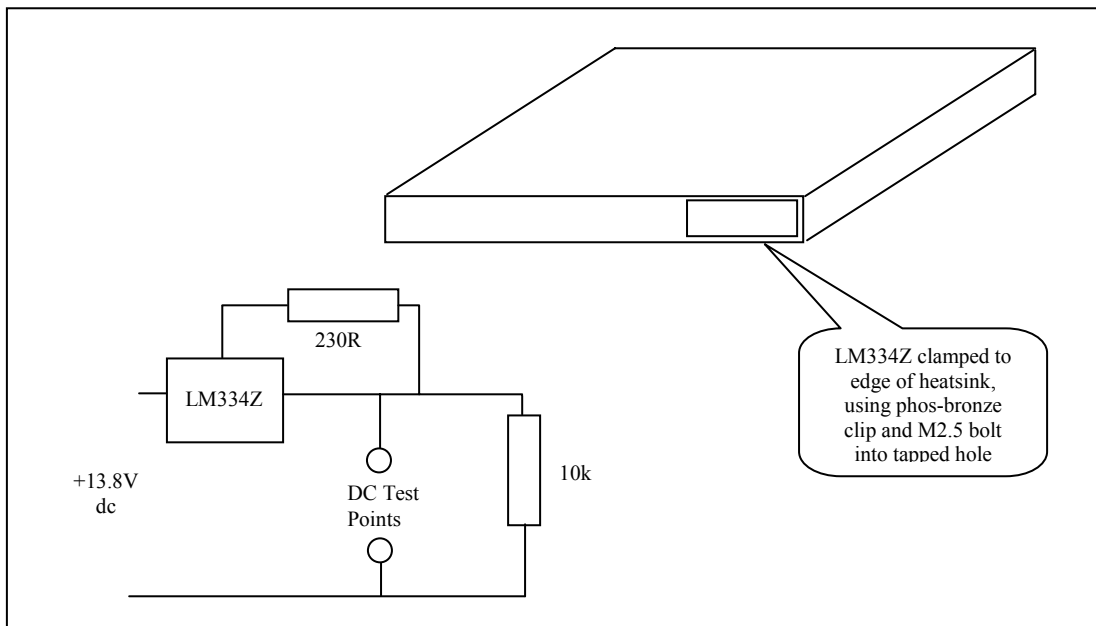


Fig 5 Additions for Temperature Monitoring of Oscillator

The RF output from the oscillator is taken to the splitter/amplifier, shown in Fig 6. A Mini-Circuits PSC-2 is used to split the signal. One path is amplified by an MAR4, and is fed to the front panel BNC connector for frequency monitoring, whilst the other path is amplified using an MAR3, and has 15V DC put on to the centre of the output coax via a bias tee. This output is taken to the N type socket on the rear panel for connection to the masthead unit. The output level at the monitoring socket (normally terminated in 50Ω) is nominally 0dBm, and via the rear socket is nominally +3dBm.

In both the rack and masthead units the inductor for the bias tee consists of 16 turns of 24 swg enamelled copper wire wound on a T50-2 toroid.

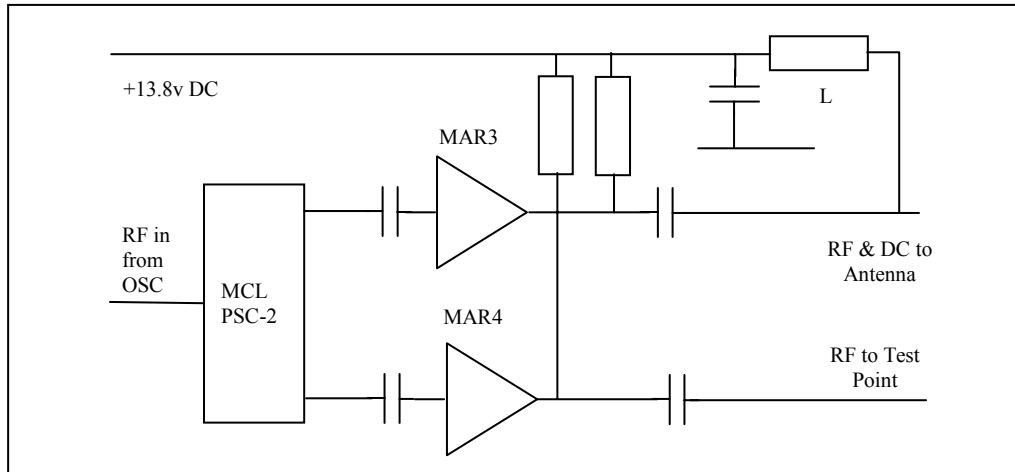


Fig 6 Splitter Amplifier and Power Feed for Mast Head Unit

GB3MHS Antenna Unit

The external antenna unit houses the x24 frequency multiplier stages, a 4 pole interdigital filter, power amplifier and a circulator/directional coupler, as well as the two antennas.

The frequency multiplier is to a design by DD9DU, and originally incorporated the oscillator stage as well. The crystal has now been replaced by the RF feed from the rack unit, which is fed onto the crystal pads through a capacitor on each side – this was necessary since, like the DF9LN and the G4DDK oscillator strips, it uses a Butler oscillator, in which neither side of the crystal is grounded. The original 1W amplifier has been removed, due to reliability problems during the testing of GB3MHS. It was also discovered at this time that the DD9DU multiplier strip leaves something to be desired in terms of its spectral output quality – the +/- 100MHz components at 2.3GHz were only around -40dBc.

A 4 pole interdigital filter was designed and constructed [5] – this improved the ‘close in’ harmonics to almost -60dBc, and a donated ex-commercial 2W amplifier was added. This is run at reduced output to ensure its longevity. The output from this, at +30dBm, is passed through a circulator, to give some protection of the amplifier against any antenna problems, and the output of the circulator is taken via a directional coupler to the antenna power divider. Fig 7 shows the design for the interdigital filter.

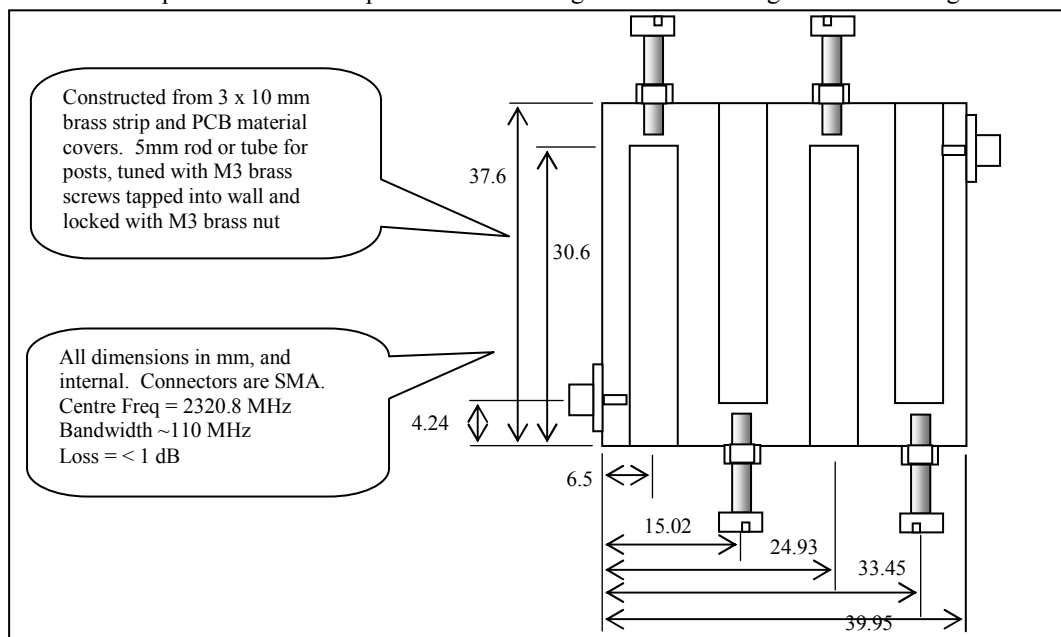


Fig 7 2.3GHz 4 pole Interdigital Filter

The directional coupler through output feeds the power divider, and the coupled output feeds a diode detector, which is used to give a DC feedback signal confirming that RF is being generated and passed to the antennas. This signal is cabled back to the equipment room where the beacon drivers are located, and is displayed via a panel meter.

The antenna panels each have 16 slots – 8 either side of a centrally mounted SMA connector, and a tapered transmission line runs to each end of the panel from this connector. Two such panels are used, giving 32 slots in total, with a gain of approx 16dBi

Construction

As already stated the rack mounted circuitry has been housed in a 1U high standard rack case – this doesn't give much available depth for connectors and switches on the front and rear panels!

Fig 8 shows the front panel of the beacon, showing from left to right the power LED (under the G of GB3MHS!), the main power keyswitch, the oscillator temperature monitoring connections, the keying LED, the non-latching keying control switch and the BNC RF Test Point for frequency monitoring – a termination is shown on this connector.

The rear panel houses the AC mains inlet and fuse, and the RF output N type connector.

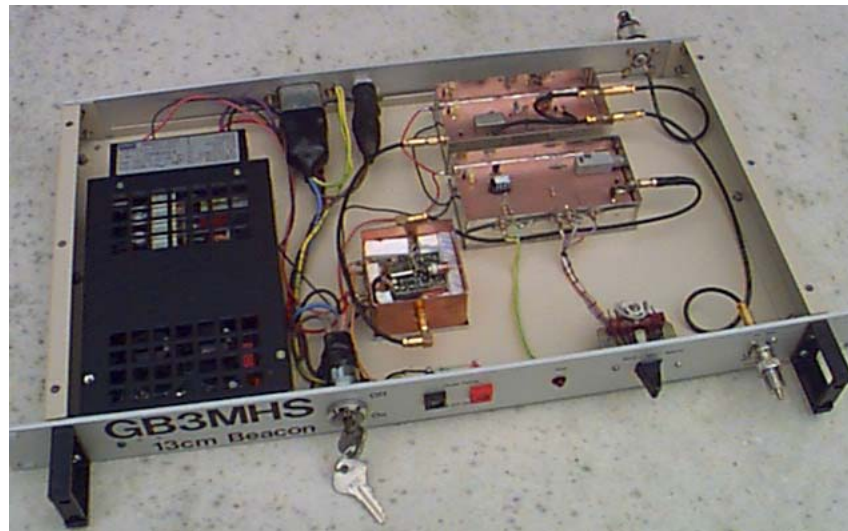


Fig 8 GB3MHS Rack Unit View

Internally, all circuitry is housed in screened cases. Each of the three schematic blocks indicated in Fig 2 is contained in its own tinplate box. The RF master oscillator is in the centre, next to the PSU—some of the insulating foam is visible around the circuit boards. The frequency trimming capacitor and the crystal are visible in the picture.

Just to the right of the oscillator is the keyer unit, housing the PIC controller, the keying transistor and the deviation adjustment – the pre-set pot is visible towards the right of the housing. The deviation required at 96MHZ to achieve 800 HZ at 2.3GHz is only about 30Hz – even using a 10 turn preset, the setting is very sensitive! The unit towards the rear is the splitter/amplifier module.

The MastHead Unit

As already described above, the masthead unit consists of two slotted transmission line antennas – Fig 9 shows a section of one antenna – and a central electronics unit. The electronics unit is built onto a

plate which joins the antennas. A fabricated half wave two-way splitter divides the output power equally between the two antennas



Fig 9 GB3MHS Slotted Transmission Line Antenna

Fig 10 show the central plate, bearing all the mast head electronics. Visible from left to right in the view are the interdigital filter, the power amplifier towards the back of the view, with the power divider in front of it, and the directional coupler and attenuator/diode detector at the front. To the right is the circulator. The multiplier strip, input connector and bias tee are all on the other side of the plate. The plate and the ground planes of the antennas themselves also act as a heat sink for the amplifier.

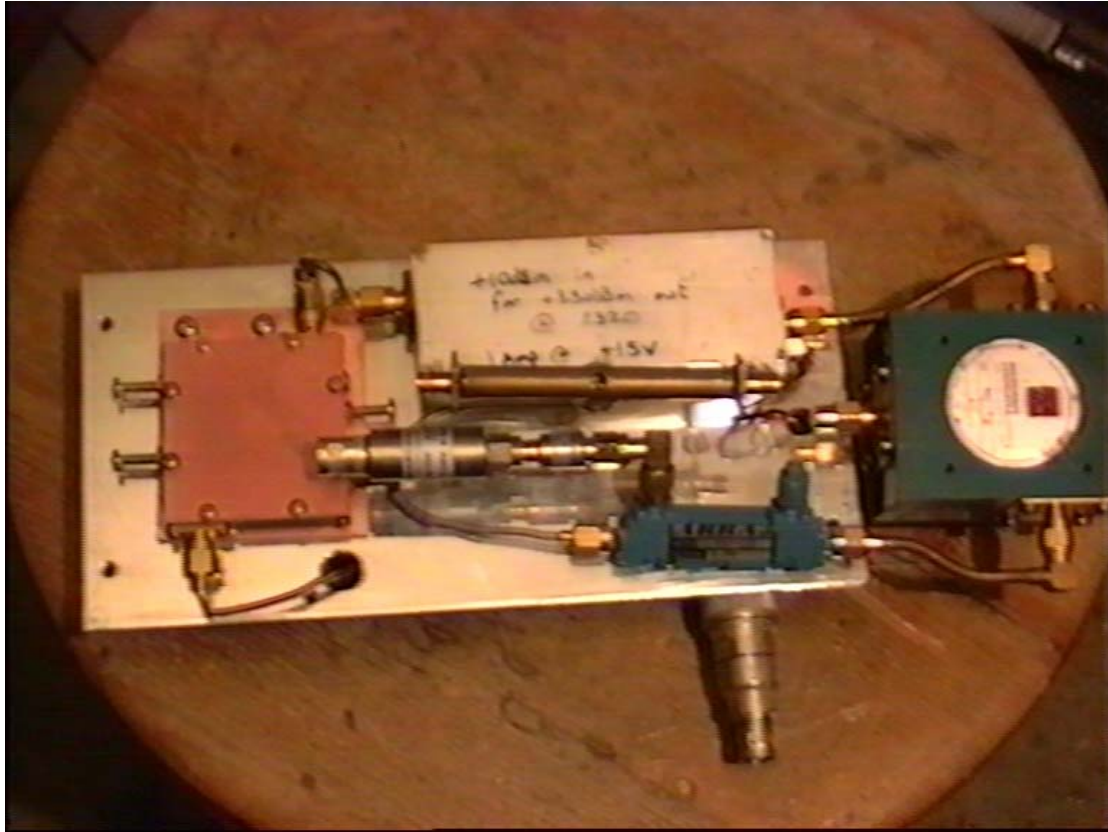


Fig 10 Central Plate of Antenna Unit

The output from the diode detector is cabled out through a second hole in the plastic tube to a junction box, where it is put onto a common multiway cable with other monitor and command lines back to the equipment room, approx 15m below.

Installation

The antenna unit is installed on the south side of the 130m steel reinforced concrete tower at BT Labs, JO02pb, in East Anglia. The mount is attached to the steel railings of the upper circular balcony, close to the top of the east facing antenna of GB3MHL, and one balcony higher than GB3MHX. A nearby location on the same balcony level as MHS is already kitted out with the hardware and feeder for GB3MHK, on 24 GHz. Fig 11 shows a view of the antenna in its mounted position, with the support and feeder for MHK visible to the left, and the top of the MHL-east antenna visible below the balcony rail level, just behind the DC junction box for the beacon monitoring cables..

The antenna radiation minima are set to the north and south, giving maximum radiation to the east and west – given the 135° beamwidth in each direction, that should give a reasonable coverage pattern inland, and to the near continent – the waters of the North Sea, and the harbours of Felixstowe and Harwich are clearly visible from the antenna site on a clear day.



Fig 12 GB3MHS Antenna Installation

The beacon installation was carried out on 8th Jan 1999, and it was officially brought into service on Friday 22nd January. The beacon has already been heard widely in Suffolk, and North Essex – all reception reports and comments are welcomed, either via the DX cluster or via e-mail [6].

Acknowledgements

I would like to acknowledge the donations of parts for the beacon, and assistance in various stages, from G4DDK, G3ZQU, G4FRE/WW2R, G4ASR, ON6UG, G4BAH, and G4FSG. The members of Martlesham Radio Society, G4MRS, are also grateful for the support given by BT's Radio Planning Division and BT Laboratories Estates Department in permitting the use of the site for beacons, and for the guidance and assistance of the local Radio Workshop staff in meeting the stringent safety standards applicable to professional radio antenna installations.

References

- [1] The Martlesham Microwave Beacons; Dave Powis, G4HUP and Sam Jewell, G4DDK, UKW 42, Weinheim 1997
- [2] GB3MHS – New 13cm Beacon at Martlesham; Dave Powis, G4HUP, UKW 43, Weinheim 1998
- [3] A microwave beacon callsign generator, G4FRE, p 9.21, Microwave Handbook, Vol 2, RSGB
- [4] For more information on the G4FRE/WW2R PIC keyers, visit Dave's website at <http://www.flash.net/~g4fre>
- [5] Interdigital Bandpass Filters, p12.32, Microwave Handbook, Vol 2, RSGB
- [6] Beacon reports via DX Cluster spots, packet mail to either G4DDK or e-mail to dl4mup@qsl.net