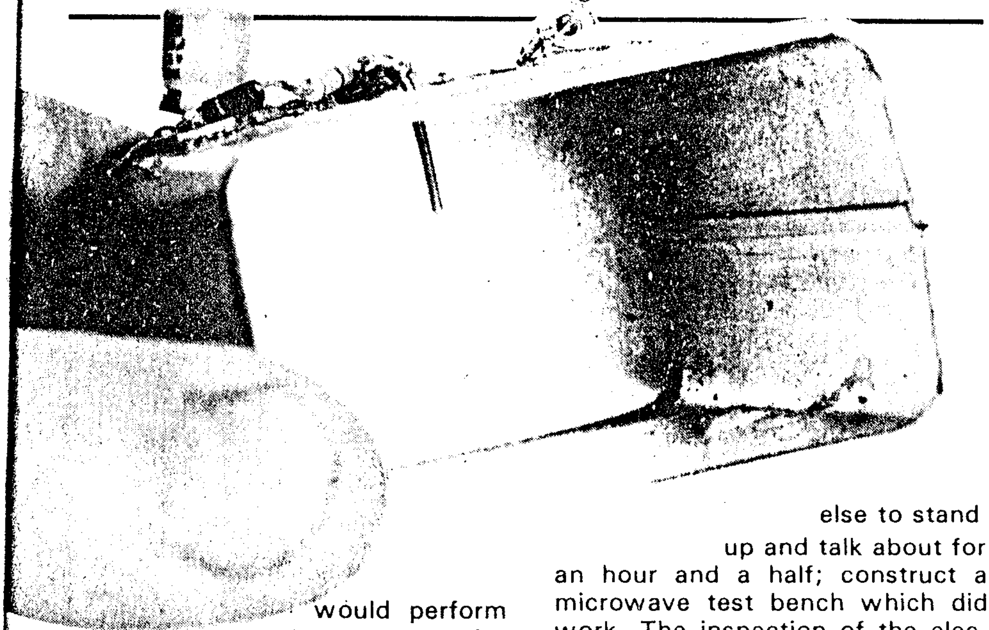
MICROWAVES with a Mustard Tin

The microwaves are an area in which amusing and informative experiments on how radio waves are propagated can be carried out. You too can feel like Marconi! Our very own Guglielmo, Frank Ogden, G4JST, describes the construction of a simple transmitter and receiver for 9cm and hints at the art of using a wok as a waveguide.



Sitting down at my bench and looking at an empty Colman's mustard tin it occurred to me that the tin with its lid off looked rather like a waveguide which had been blanked off at one end. Could it be that it would perform like a waveguide resonator? I set about finding out.

I had been asked by a local radio club to give a lecture — subject of my choice — with the request coming at fairly short notice. I decided that a microwave demonstration would be interesting — I could show how radio waves could be bent, reflected, polarised and focussed — all in the space of two village hall trestle tables.

With two days to go before the lecture I pulled out my old 10GHz Gunn oscillator and fired it up to make sure it worked. I lined up the detector, connected up the meter and. . . nothing. With rising panic I discovered that the fragile barrier diode in the detector assembly had blown, presumably due to static. The Gunn source still functioned OK but I had nothing which received efficiently at the operating frequency. I had three choices: cancel the lecture; find something else to stand up and talk about for an hour and a half; construct a microwave test bench which did work. The inspection of the electrical properties of a mustard tin followed course three!

I say all this to put the design which I offer into perspective. The total time taken to design, build, de-bug and evaluate the transmitter and receiver was approximately five hours. What follows is surely nowhere near optimum, but provides a good starting point for reader's own experiments. Since the entire project should cost under a fiver, there is no excuse for not building one.

Details Of The Link

The link comprises a single transistor oscillator producing around 50mW at 3400MHz (8.8cm wavelength) coupled into the mustard tin waveguide by a capacitative probe. The link uses amplitude modulation produced by applying audio to the base of the oscillator transistor. In its simplest form, the transmitter aerial is simply the open end of the mustard tin radiating into free space.

The receiver comprises a UHF Schottky mixer diode connected to the centre of a broadband 'butterfly' dipole. The diode, which is biased into conduction by a very small DC current feeds the demodulated signal into a very sensitive audio amplifier. Needless to say, the gain of the overall link (and thus its range) can be increased considerably by focussing both the transmitting and receiving radiators with dustbin lids, frying pans, Chinese woks (the author's personal preference) and other bits of metal.

The range of the link is not quite up to Marconi's experiments from Poldhu, Cornwall but is demonstrably a lot better than Hertz's. The first attempt with my experiment produced ranges of several hundred feet. Superior aerial arrangements would improve this considerably.

The Transmitter

Fig.1 shows the schematic of the sender unit. The single transistor oscillates by feeding RF from the tuned collector to the emitter via the internal capacitance of the device, a BFT95 'T' package transistor. Please note that this is a PNP type and thus requires a negative supply for its collector circuit. This type of transistor was intended as a low noise, high current RF pre-amp for TV tuner service. Its high fT of around 5GHz makes it eminently suitable for this type of oscillator.

Construction of the sender unit is essentially a mix of solder and super glue. The collector circuit,

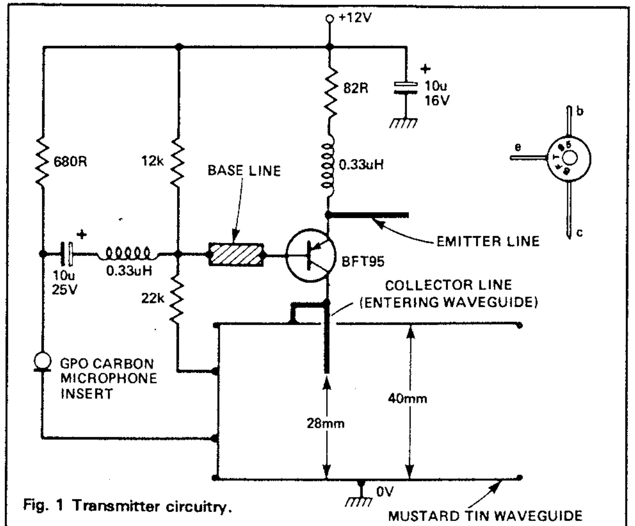


Fig. 1 Transmitter circuitry.

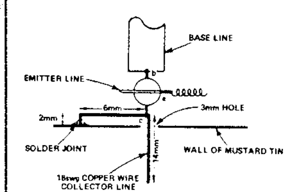


Fig.2 Detail of collector line for 8.8cm oscillation.

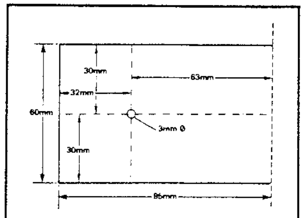


Fig.3 Drilling dimensions for the tin.

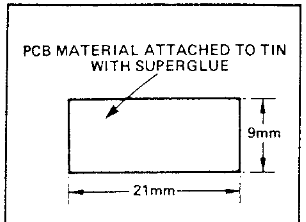


Fig.5 Dimensions of the base line.

electrically a quarterwave line grounded at one end, is a right angle of 18 SWG bare copper wire of total length 22mm. The 'hot' end passes through a hole drilled into the mustard tin waveguide. The 'cold' end has its last couple of millimeters bent into a small foot which is then soldered directly to the outside of the tin. The collector of the transistor (the long tab) is soldered directly to the collector line about 6mm from the earthy end (ie the cold end that is now soldered to the tin). The device should be soldered with the tab so short that the collector line is hard up against the transistor case. *Care should be taken during this operation that the transistor isn't cooked.* **Fig.2** shows the detail of the collector line; **Fig.3** gives the drilling details of the mustard tin while **Fig.4** shows the plan view of critical components which are active at microwave frequencies. Placement of other connector

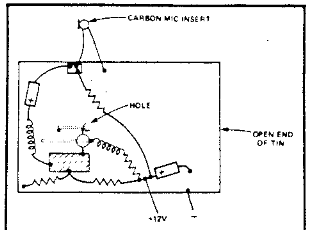


Fig.4 Layout of oscillator parts on top of mustard tin. Microwave critical parts are shaded.

'pads' — bits of PCB material held on with super glue — can be made at the convenience of the builder.

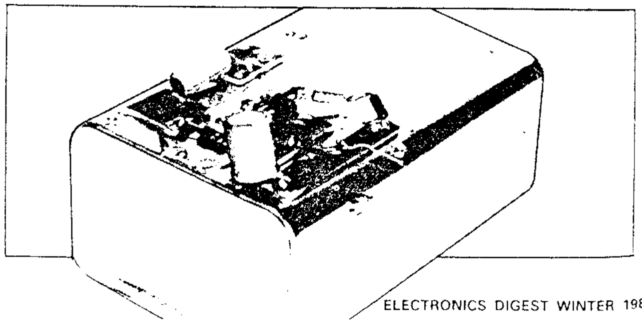
Note that Fig.4 also shows a base line, a low impedance quarterwave stub to ground the transistor base at the operating frequency, and an emitter line, a short bit of wire hung onto the emitter connection. Although not essential to oscillator function, this last addition was found to boost efficiency of the circuit substantially.

The base line is essential. This is a super glued piece of circuit board with the dimensions shown in **Fig.5**. The output frequency of the oscillator is determined by the length of the collector line. More about this later.

The circuit (Fig.1) shows a number of low value RF chokes scattered around various parts of the circuit. The prototype used 0.33 microhenry commercial subminiature units but five turns of 22 SWG wire wound as a 3mm airspaced coil (use a drill bit to wind these on) would do equally well.

The Receiver

The microwave part of the receiver is apparently just a simple broadband dipole mounted on a miniature ceramic tag strip. The Schottky mixer diode is mounted directly across the dipole with a



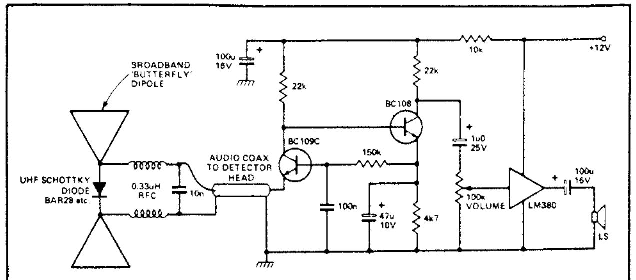


Fig.6 Complete receiver circuit.

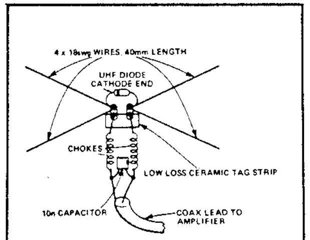


Fig.7 The receiver microwave head.

pair of small chokes taking the rectified signal to a piece of audio coax. The overall receiver circuit is shown in **Fig.6**. The details of the receiver microwave head are shown in **Fig.7**. The 10n capacitor connected across the cold end of the RF chokes is essential to prevent broadcast interference breakthrough.

The prototype audio amplifier was built on an off-cut of veroboard. There is nothing special about construction except that the audio loudspeaker output should be kept away from the amplifier input.

The first stage of the preamp performs two functions: it provides around 50 microamps of current to bias the detector diode to maximum sensitivity while the emitter input configuration provides a good impedance match to the audio output from the diode. The result is a receiver which is much superior to the basic crystal set which it appears to be.

Testing And Frequency Measurement

Having soldered and stuck the sender unit together, the obvious thing to do is to test it. Connect the unit to a 12V low impedance supply. The current drawn should be in the region of 30 to 40mA. A finger placed on the collector line should alter the current reading or stop oscillation altogether. The current should drop to around 5mA in the latter case. Placing a hand across the mustard tin waveguide mouth should also reduce the current. The transistor runs quite hot even under normal conditions.

The prototype could light a small bulb (1.2V 100mA) quite brightly by placing the bulb with a couple of 'dipole aerial' leads attached (20mm each) inside the waveguide. *There is clearly quite a bit of microwave power about and the waveguide exit should be kept away from the head and — particularly — eyes.*

Decouple Well

Working near its upper frequency limit, the transistor presents a negative resistance to the supply. Low frequency RF oscillations can result unless the supply is well decoupled. This same effect makes it quite difficult to obtain deep amplitude modulation with a simple carbon microphone connected as shown. This part of the circuit would doubtless benefit from further circuit development.

Crude but effective frequency measurement may be made by stretching a length of bare copper wire about 2mm above a large surface of copper clad PCB material (copper side to the wire). The wire is soldered to the edge of the board at one end while the other is connected to a UHF diode such as a BAR28 or a germanium OA91 unit. A sensitive microammeter is connected between the other end of the diode and the ground plane. When the wire line is irradiated with RF from the waveguide, the meter will show a deflection due to rectified RF.

A shorting bar slid along the wire and PCB ground plane will produce a series of peaks and troughs in the meter reading. Physically measure the distance between nulls on the wire and multiply by two to give you the operating wavelength.

The receiver when working correctly should produce masses of white noise with or without an incident signal on the detector head. In any case, the detector should produce a large reading when connected to a microammeter rather than the amplifier for initial checking with the microwave source in close proximity. Please note that the amplifier circuit will not function without the detector head being connected. Incident microwave energy does not quieten the white noise but doppler effects, microphony of waveguide, etc should at once be evident.

A Few Experiments

The first thing to note about the RF coming out of the mustard tin is that it is vertically polarised when the mustard tin is on its 'flat' side. The receive butterfly aerial must therefore be parallel to waveguide probe axis ie vertical. As well as radiotelephony using the carbon mic (why not build two links for true two-way QSOs?) the receiver and sender placed close together act as a dual cavity doppler module, as in the typical intruder alarm. Interferometer experiments can also be carried out. For instance, some types of wrist watch placed in the beam will reflect incident RF off the internal moving parts back to the receiver head. This mixes with directly received RF to produce an audible result similar to an 'X ray' microphone ie a very loud tick tock! Classic distance and wavelength experiments can also be done.

A miniature aerial testing range could also be made but this is something that I haven't tried (*G6CJ's famous 'aerial circus' works along those lines — Ed.*). The possibilities are endless. Speaking from a purely personal point, this is one of the most interesting projects that I've carried out for a long time. I am sure that those who build it will have at least an equal amount of fun.