Microwaves for the radio amateur — 6

The final article in this short series of articles written to stimulate activity on the amateur microwave bands. The author continues the description of a practical 10,000MHz station, and concludes with advice for those thinking of building up a system.

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There are three sections in the IF system, each a physically enclosed and screened sub unit — viz. IF pre-amplifier, main IF Amplifier, and limiter discriminator. For ease of understanding these will be described in reverse order.

Limiter Discriminator. This consists of a four stage broad band amplifier using high gain-bandwidth transistors type BSX19 (2N2369). Between adjacent pairs back to back fast, low-capacity silicon diodes are fitted, and these constitute the limiting devices. The output of this chain is fed, via an isolating network, to a further pair of BSX19s whose collector loads are tuned to 25MHz and 35MHz respectively. Each feeds a rectifier diode, the outputs of which are combined and fed to the audio amplifier. This latter arrangement constitutes the discriminator and contains the only tunable components in the limiter discriminator module.

A rather "brute force" method of achieving a very linear characteristic for the discriminator was evolved, by having L, C and a low value loading resistor all variable. The electrical centre of the output network is determined by a potentiometer, and since the voltage at this point is, of course, (within the linear range of the discriminator), proportional to the input frequency, it is also a convenient point to insert the tuning meter, which is a centre zero ±50uA meter with a series resistor such that it reads about 0.35V peak to peak full scale. The normal maximum reading, with full limiting taking place is about two thirds of this. The discriminator characteristic is shown in Fig 21(a).

The prototype limiter discriminator used (BF115s), and performed very well except that it was difficult to achieve more than ±4MHz. It was for this reason that the BSX19 was used in the second model, with the immediate result that just over ±5MHz with better linearity was achieved. Experience has shown the BF115 version is adequate for use with the more stable klystrons of the CV2282 variety, but the BSX19 version is possibly better for 2K25 / 723 A / B's. Some extra gain is available with the BSX19 strip, but this is of no real consequence since adequate IF gain is provided by the circuit about to be described.

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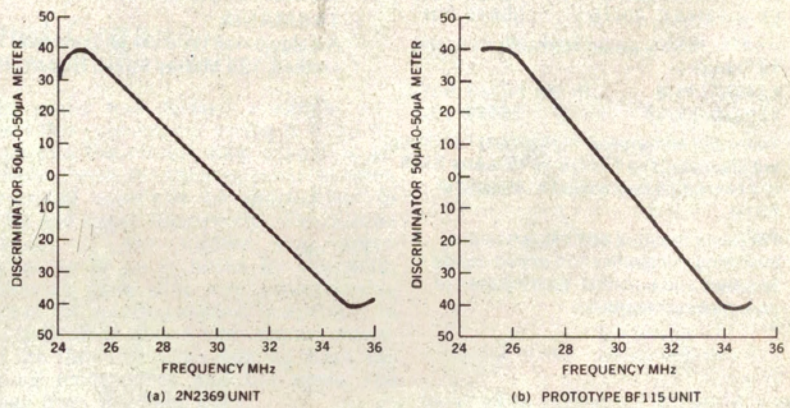


DISCRIMINATOR CHARACTERISTICS

Fig 21: Characteristics of both the author's discriminators.

Both versions were lined up with a conventional signal generator, and later checked against a sweep generator. The results were almost identical although of course the latter method was by far the easiest and gave a lot more information about the out of band responses.

The construction of the limiter discriminator is very simple. A piece of cheap single sided laminate board using Zephyr pins has the components laid out in a manner following the actual circuit. The BSX19 version uses small heat sinks; it takes approximately twice the current of the prototype, and is completely enclosed in a screening box.

Intermediate Frequency Amplifier: This operates at 30MHz and is broad banded to have a response flat to ±3dB over at least ±4MHz (±2.5MHz in the prototype). The design is based on that given in the Motorola Data Book on integrated circuits, and uses 3 MC1550G HF integrated circuits.

It exceeded all expectations both as to simplicity of construction and, after some initial teething troubles, the achievement of the desired performance. In order to gain experience in this relatively new field the writer decided to build the prototype IF strip to one design given in the data book, and the second version to an alternative design in the book and compare the results.

Design 1 in the data book is a three stage stagger tuned arrangement using four tuned transformers capable, it is claimed, of a 6MHz bandwidth at 45MHz centre frequency and having a controlled gain between 6dB and 70 dB. After conversion of the design parameters to a 30MHz centre frequency, and construction in a carefully screened three partition box, it was found impossible to secure stable performance despite the later aid given by a sweep generator.

A compromise was therefore made, by replacing the two centre tuned transformers with small broad band toroids. This immediately gave the stability required with a gain of 50dB, controlled by the application of a variable voltage to pin 5 of the first MC1550G. It was decided to settle for this and secure the extra IF gain required in the IF pre-amplifier.

Design 2 in the data book deals with a two stage amplifier, also for 45MHz but with a gain of only 30dB over a 15MHz band. The bandwidth is achieved by the simple process of resistance loading the tuned circuits which in this case are simple parallel tuned circuits.

Conversion of this design to 30MHz, with a bandwidth of 8MHz or more showed that three stages would be required. This was adopted and produced with a slightly less complicated screening arrangement than in the prototype. The adjustment of the loading resistors was made on the basis of stability, and surprisingly enough, the desired result was achieved with a gain of nearly 60dB. Gain control in this case, as in the data book, is by application of a variable voltage to pin 5 of all three stages.

The writer's conclusion is that the parallel LC loaded version is by far the easiest to produce and tame, and certainly will be used in future versions.

In both versions the MC1550G's are mounted in "holders" forming part of the printed circuit board chassis in a manner that most of the transistors in the equipment are in fact mounted. A pilot hole is drilled with a N0 50 (or thereabouts) drill. A tool, similar to an end mill, but made from a discarded ¼" drill is then used to take away the foil. The small hole is then opened out to take the appropriate pin. In the case of the IC's, the tapered Zephyr pins designed for the small matrix board are used.

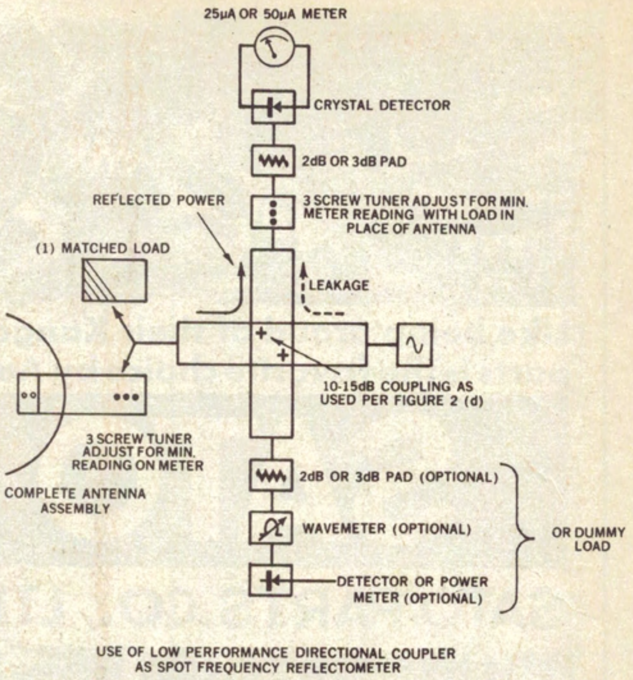
The convenience of this method of construction is that one can put in the holes as one progresses along the circuit. It therefore produces a very neat prototype arrangement without the need for etching.

Pre-IF Amplifier: The outboard pre-amplifier for the IF system serves two main purposes, viz,

(i) It provides a most efficient and low loss method of transferring the very low level IF signal developed in the mixer crystal to the main IF amplifier.

(ii) It provides sufficient extra IF gain so that experiments can be performed to determine the optimum settings of both the pre-amplifier and main IF amplifier gain controls, and if necessary introduce additional attenuation between the two, or between the main IF amplifier and limiter discriminator.

Fig 22: Showing the use of a low performance directional coupler as a spot frequency reflectometer for adjusting matching of the aerial.



The latter step was thought advisable in view of the possibility of instability in the IF system as a whole, and has proved quite a useful feature. As shown in Fig 20 the output of the crystals is fed, after filtering off the DC crystal currents, to a low noise BF 180 amplifier with a bandwidth of some 15MHz. This is operated as a variable controlled gain stage and has its output fed to an emitter follower which in turn feeds the main IF amplifier by a length of 50ohm coaxial cable.

Initial experiments have confirmed that the main IF Amplifier and limiter discriminator of the design of the second set of equipment really are sufficient for all but the most distant contacts and the pre-amplifier is therefore a bit of a luxury which could be added later when the feel of the system has been obtained. However it does appear that the pre-amplifier is a necessity with the prototype set. This pre-amplifier is of slightly different design, and fed from a single crystal mixer used a pair of TIXMO5 low noise germanium transistors operated in a cascade arrangement, and also working into an emitter follower and thence the Main IF Amplifier. Its circuit is also shown, for general information (see last month.).

Microwave system: Two 17" diameter parabolic reflectors using feeds to the design of Fig 16 are used in the complete system. They have gains of approximately 30dB and a beamwidth of between 4° and 5°.

The upper parabola is firmly fixed to the main framework of 1¼" x 1¼" x ⅛" aluminium angle, whilst the lower parabola is fixed to it in the same manner but via four double coil spring washers. Thus the tensioning of the screws through these washers gives a fine degree of movement. In the first instance, and before the feeds are fitted, the perimeters of the two parabolas are adjusted to be flush by placing them face downwards on a large flat surface.

The klystron feeds the top parabola after having some 5mW of its power extracted via the directional coupler, which is of the type illustrated in Fig 10. In order to present a very good match to the klystron a three screw tuner is built into the feed and this is adjusted with the feed and parabola in their assembled form. A dummy load of the type shown in Fig 11 normally terminates the unused side arm of the coupler. For test purposes, a signal can be fed in at this point, by substituting either a waveguide adaptor or a waveguide to coaxial transformer for connection to the signal generator.

The antenna feed can also be adjusted for minimum reflection, as follows:

(i) Connect the coupler as shown in Fig 22, and use as sensitive a meter as is available. Note that the aerial is replaced by a good matched load. The addition of the wavemeter and power meter to the lower side arm is not essential. If these are not available, replace the normal waveguide to coaxial transformer by a dummy load.

(ii) Adjust the screws on the upper side arm for a minimum reading on the meter. What is being done at this stage is to cancel out the leakage component which is due to the fact that this type of coupler does not have a high directivity. This screw setting only holds at one frequency and the procedure must be repeated if the frequency is changed.

(iii) Replace the complete antenna (feed and parabola), and point it towards free space, then adjust the three screws on the rear of the feed for minimum reading on the meter.

(iv) Replace the dummy load on the upper side arm of the coupler, and the waveguide to coaxial transformer on the lower one, and the assembly is back to normal.

In this equipment the klystron is a CV2282 with a direct waveguide connection so it is bolted straight onto the rest of the assembly. It is enclosed in a brass box to exclude draughts and temperature changes which do affect the frequency of reflex klystrons, particularly the 2K25 series. These can easily be "blown" 10MHz off tune!

The incoming signal is collected at the focus of the lower parabola and is fed to the 3dB coupler where it divides equally, and enters the twin crystal mixer cavities. At

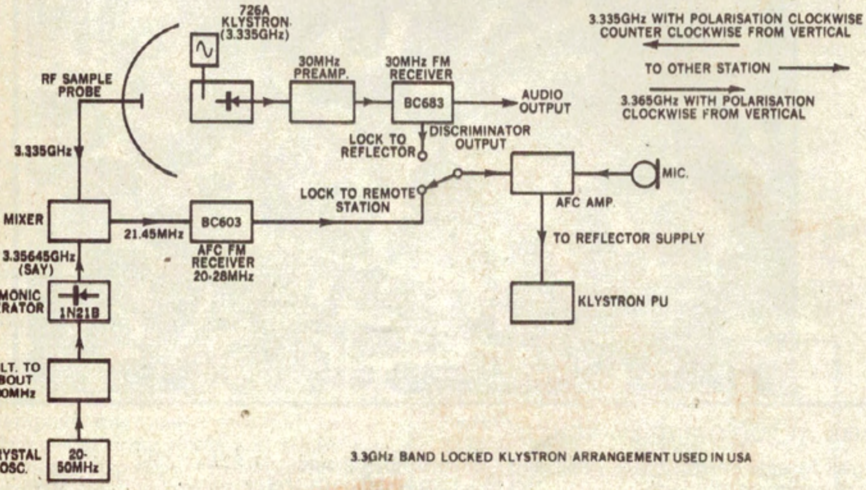
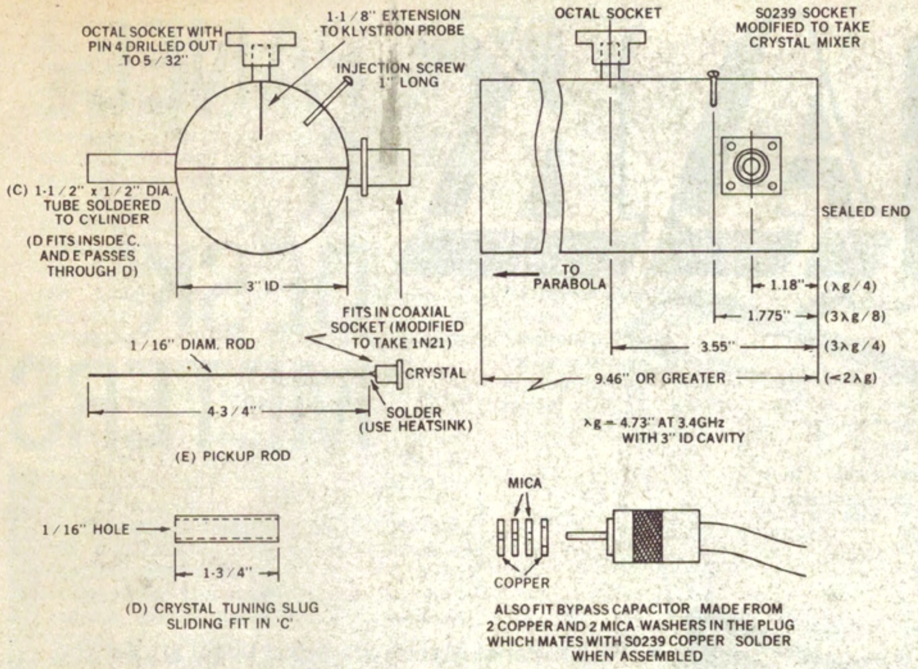


Fig 23: Basic details of the locked klystron scheme used by some US amateurs on the 3300MHz band.



CONSTRUCTION OF 3.4GHz POLAPLEXER (TAKEN FROM QST JUNE 1963)

Fig 24: The construction of a polaplexer for use on the 3300MHz band, taken from an article in the June 1963 issue of "QST."

the same time the local oscillator signal which is, of course, separated by 30MHz from the incoming signal, is fed to the 3dB coupler by the waveguide to coaxial transformer. This signal also separates equally and enters the mixer cavities. The output of the crystals at the IF is roughly the same as that which would arise from a single mixer, but with the added advantages that there is a considerable amount of isolation (10 — 20dB) between the signals and local oscillator, and that there is a considerable cancellation of local oscillator noise.

Other systems in use by amateurs: The equipment described in the previous sections is representative of that used by the majority of amateur microwave stations throughout the world. An alternative to the use of "free running" klystrons is the system evolved for use in the 3300MHz band by a group of US amateurs. Since this system also uses the polaplexer technique referred to previously, a block diagram and a few notes will be included.

Figure 23 illustrates the techniques of locking klystron to either the harmonic of a local crystal oscillator / multiplier chain, or to the signal received from a remote station so equipped. Its main advantage is that it allows the use of narrow band IF amplifiers (the surplus units referred to in the original QST article could, no doubt, be replaced by one of the many similar mobile FM radios which are available at present), with consequent improvement of overall system performance. It suffers from the disadvantage that it is a little more complex, but is well worth considering for really long distance contacts.

Figure 24 illustrates the construction of the complete microwave assembly for a 3300MHz polaplexing system. It is obvious that its simplicity requires little more than the klystron and a suitable reflector, in order to be able to put oneself on the air. This technique should certainly be considered seriously for use at both 2300 and 3300MHz in Australia.

An article in QST November 1963 describes some equipment for 10,000MHz which is really the ultimate in complexity as far as the amateur is concerned. It uses direct crystal control of a klystron multiplier fed from a 2000MHz multiplier chain ending up in 2C39A and 3CX100A5 triode stages. The writers of the article are to be complimented on their enthusiasm and are quite correct in making the point that an overall system gain of up to 40dB could be achieved by such a system working into a narrow band communication receiver.

It is felt, quite sincerely, that such equipment is not truly representative of the average worker in this field. However, a careful assessment of the many features of equipment from all sources should be made by the amateur intending to participate in the microwave field, as over the years some positive contributions to the science of radio communications have been made in the amateur fraternity and not all these techniques date as easily as some of their lower frequency equivalents.

In concluding this short series of articles, it is hoped that they may have served to stir up interest in the idea of experimenting on the microwave bands. If only a few readers have been encouraged to try their hand at amateur microwaves, the effort of the writer in producing the articles will have been worthwhile.