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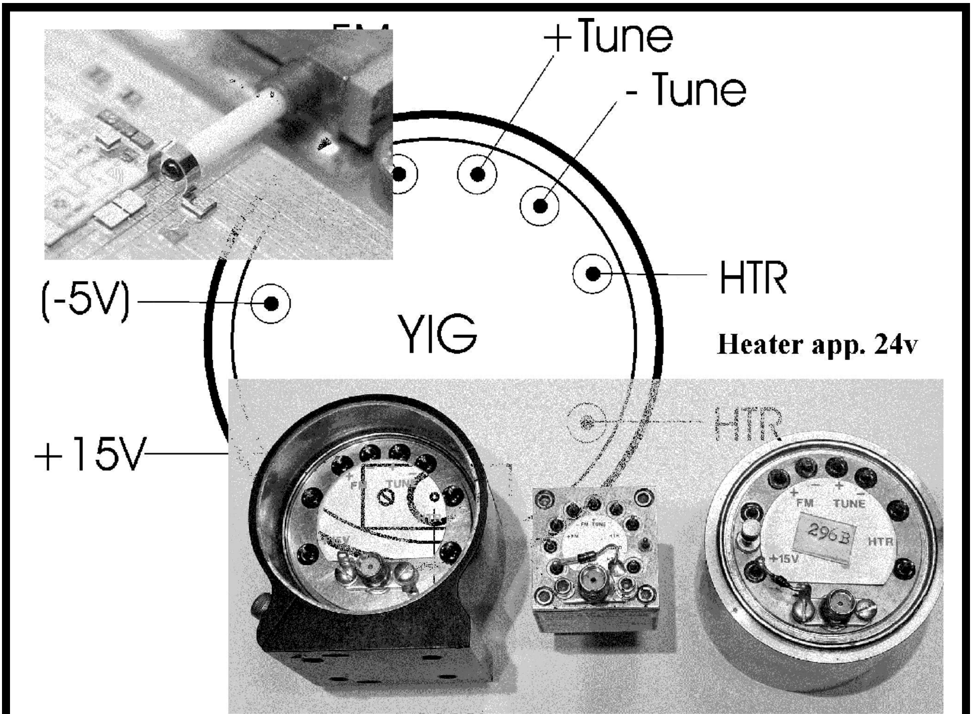

A simple approach to YIG oscillators

Alexander Meier, DG6RBP

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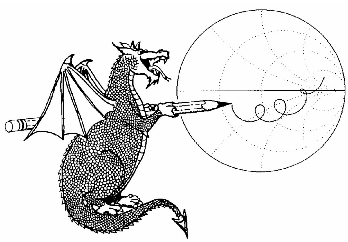

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Contents

Lots of different articles again in this issue. It is nice to see some different authors and it would be nice to see even more new authors. If you have been working on a project and think that it would make a good article please contact me.

Another year has passed and it is time to renew your subscription for the new year. There will be a small price increase again this year, mainly to cover increased postal costs. If you normally subscribe directly with me there will be a form with this magazine, otherwise you can contact your local agent (see the inside back page for a list of agents) or use the form on the web site.

Merry Christmas and a Happy New Year.   73s - Andy

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Carl G. Lodström, SM6MOM & KQ6AX

The Noble Art of Optical Communication Part 1

Communication over the air with a beam of light

Carl helped with the translation work for the article on Amateur use of the optical spectrum published in issue 1/2004. It was obvious that he is very knowledgeable on optical systems so I was very pleased when he said he could produce an article for VHF Communications in his normal, very practical style, to describe how amateurs can actually use light for communications. There are some colour photographs and audio clips on the web site to accompany this article – Ed.

1.0 History

Not counting smoke signals and semaphores, on June 3 1880, Alexander Graham Bell used the first real optical communications link. It was his innovation and design. A small mirror, which sensed the vibrations of a voice, modulated light from the Sun. The receiver was supposedly some kind of selenium cell. I do not know if it was used in a photovoltaic or a photoconductive mode. Both Tx and Rx used parabolic reflectors of almost 1m diameter and I remember reading that the distance he covered was of the order of a kilometre. Bell called his invention “Photophone”.

While I was preparing this article I spoke with an old friend, Christer Falkenström - SM4DZR, he reminded me of a device called "The Lichtfernsprecher". This was manufactured by Zeiss and was based on modulating a light bulb mounted in some form of binoculars. I found some references to this on The Internet [1 -3]

The only attempts I have seen (Palomar Amateur Radio Club around 2001), of optical communication devices among ham operators, used a VCO, LM555, LM565 or similar, at about 40kHz, modulating a LED or a Laser Diode. The receiver was a photo detector, a 145MHz LO and mixer on the input of a regular 2m FM rig, where the signal could be heard 40kHz from the LO. The only advantage with this may be that they can use regular LED’s, IR or any other colour. I do not recall that they demonstrated any “Solar blindness” performance, so communication may have been limited to dark areas and hours.

2.0 Background

For over a decade I have had the notion of making “Amateur Radio” contacts with light, by reflection from buildings or scattering in clouds. In this scheme nor-

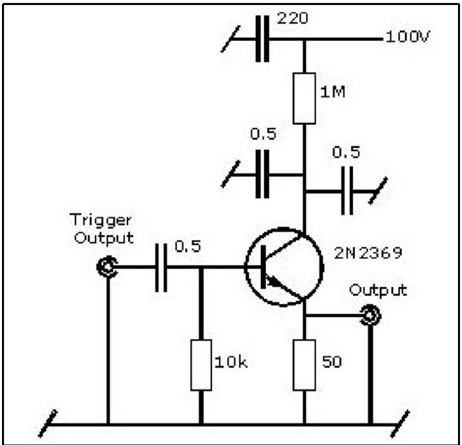


Fig 1: The avalanche impulse generator.

mal radios would be the modulators and the demodulators, no sub carriers. Just recently I finally I got around to build something to try it out in practice. I found that it was not so easy, if possible at all, to reflect detectable signals off buildings or clouds, at least not with laser levels that are even moderately safe. The 15mW diodes I use, do not seem to be powerful enough, and yet they are strong enough to damage an eye. I have tried pulsed RF and just a very short impulse fed to the Laser Diode. Aiming it at a shopping centre approximately 200m away I hoped to see the reflection on the scope just over a µs later, but no! There was nothing. I lowered the bar and tried it in the backyard, approximately 15m away. Now I could detect the reflected impulse, but only from a vehicle reflector (which is very good) and not from a reflective license plate.

I saw the impulse generator shown in Fig 1 described by Linear Technology's Jim Williams. It is utilizing an avalanche breakdown in a transistor at some 100V, generating a very sharp impulse. My sampling scope has a $t_r = t_f$ of <300 ps and yet, all I see is an approximately 500ps wide impulse, the rise time of the scope itself! It puts approximately 8V in 50Ω, so it is a serious pulse, but the repetition frequency of some 100kHz, depends on the voltage applied, the Laser Diode survives. When looking at the noise on a spectrum analyser, I see the forest up to some 2GHz, so a $t_r = t_f$ of some 175ps is a good guess. Jim says that not all transistors work in this application, but that 2N2369 is a good candidate, I do not remember why. I have added the trigger output and built 3 of them and all worked. If you ever get to detect your reflected signals, this is the generator for making the impulses! The output goes straight to the Laser Diode. The output is positive, if the diode needs a negative polarity, the little transformer described later comes in handy so you can ground the Laser Diode package. With a wide band Directional Coupler it is great for TDR measurements in cables! I have seen the reflection in a 15cm long coaxial cable with this device!

The last word may not yet have been spoken about light communication by reflection. At least I have come up with some results, as well as a few possibly useful circuit solutions that are describe in this article. These circuits that may carry the Laser Diode torch further into the future.

3.0

Some fundamentals

The flux of light, a flux of electromagnetic power is measured in cd (candela), one of the seven fundamental SI units. When the flux of 1cd is distributed over $1m^2$ the illumination is called "1 lux". If it is distributed over $1ft^2$ (0.3048 x 0.3048m) the illumination is of course about 9 times stronger and called "1ft cd". As $1ft^2 = 0.0929m^2$ and $1m^2 = 10.764ft^2$ => 1 lux = 0.0929ft cd.

The isotropic source, which is an imaginary device for RF and antennae, is nearly possible with light! A regular

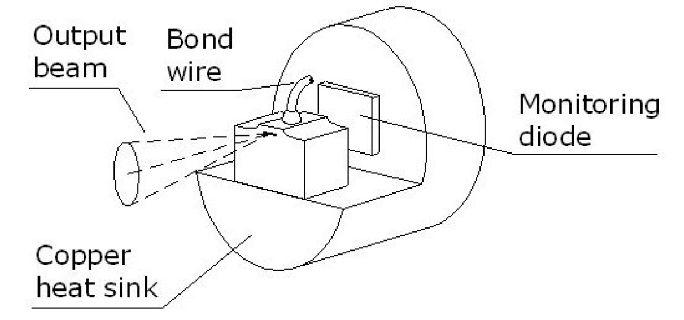


Fig 2: The laser diode.

candle shines almost equally strongly in all directions. Of course, it is shaded by itself in the straight down direction, but if we forget about that detail it is easy to imagine a 12.56cd light source in a sphere with R=m. The illumination of the walls will then be 1 lux. The surface of a sphere with a 1m inside radius has an area of 4π or 12.566m².

The volume angle that one square meter occupies on the inside of the sphere, as seen from the candle in the centre, is called a steradian so there are 4π steradians in one sphere.

3.1 Properties of an emitter

Here the basic emitter, “Tx”, is a light source that can be modulated. That is: turned on and off, or varied in strength (AM) by a radio frequent signal. This RF signal can of course in itself be modulated by AM, FM or by any other mode, including CW. In CW the light would be on all the time, but with key down it would have RF modulation. To the eye no modulation would be visible.

Incandescent light bulbs can be used up to about 10KHz. After Christer reminded me about "The Lichtfernsprecher" I measured some small light bulbs and found that they have a flat response up to 500Hz and are only -7.5dB at 3KHz.

LED’s are not much better, they may be willing to be modulated up to some 100kHz, but this barely reaches anything that our radios can generate or detect. They can be used for audio modulation though, and there are some pretty intense LED’s available, not the least in the infra-red (IR), with an output of several candelas. Remote controls for home electronics usually operate with modulated IR light in the 100kHz range.

3.2 Properties of the Laser Diode

Laser Diodes are the emitters of choice for the Ham operator! They can be modulated up into the UHF range, and more. Some telecommunication equipment for optical fibres is already operating up to 20GHz.

A simple DC measurement on a Laser Diode reveals some kind of dynamic resistance. For an IR device one has to first apply about 1.6V before it draws any current at all. The diodes I found on eBay, Mitsubishi ML5101A, are marked as having an output of 15mW at 830nm with an operating current of about 69mA. Fig 2 shows the construction of this diode.

They do not “lase” until a threshold current is reached, around 15 - 25mA, a bit different for different diodes even of the same kind. Above this current, the light output takes off, and it does so in a fairly linear fashion. Just below the threshold current, the light output is not

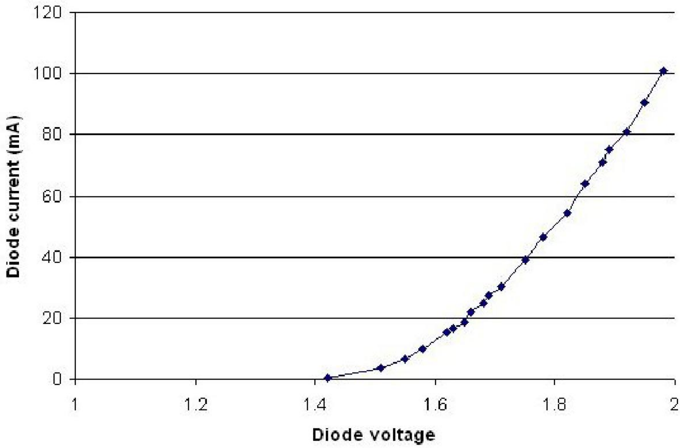


Fig 3: The DC characteristics of the IR laser diode.

monochromatic, but consists of a "mole hill of sidebands". Above the threshold current the most central of the peaks grows rapidly as the current increases, and the "sidebands" become insignificant in comparison. I measured the distance between the peaks to be some 0.28nm. This corresponds to a 123.9GHz "modulation" (of the 364,4THz carrier, in the IR part of spectrum), corresponding to a λ of 2.42mm. I would not be surprised if the length of the Laser Diode chip is half this, 1.21mm, divided by the the refraction index in the material. Inspired by this, I listened with a receiver, connected to the photo-detector described later, to the signal from a Siemens Helium-Neon (HeNe) laser (LGK 7639) that is in a 28cm long housing. Sure enough, at 634MHz there was a strong signal, on AM and FM, which drifted back and forth by ±0.2MHz. Probably the distance between the mirrors change with temperature from draft in the room. λ/2 for 634MHz is 23.7cm in air.

There is a very small slit in the Laser Diode chip, from which the light emanates. It is only a few wavelengths (λ) wide and not very long either. So the light from the diode is diffracted and is emitted as an elliptical beam. I measured roughly 16° x 6° (either side of the centre line) on my diodes.

Fig 3 shows the DC characteristics of the IR Laser Diode. Notice that the X-axis starts at 1V! No particular discontinuity was observed at about 15 mA where the diode "comes alive".

Around I_D = 30mA the slope is approximately 5Ω. This was also the value found to be the approximate RF impedance, as could be expected. A 3:1 turns RF transformer (Z = 9:1) gave a -12dB return Loss at 145MHz on a 50Ω reflectometer. It is very possible that some reactive component can be tuned out as well, but this is good enough.

Fig 4 shows the DC current from the built-in Monitoring Diode vs. Laser Diode current. Clearly the Laser Diode "takes off" at about 17mA, the Threshold Value just as it is marked on the package the diode came in. The Monitoring Diode can be used to control the current to the Laser Diode. The light output level can thus be kept constant. In this case a little 500µA or 1mA meter could be connected directly for indication of operation. The normal operating current of 69mA was exceeded for purposes of this measurement only. The diode survived, but in the

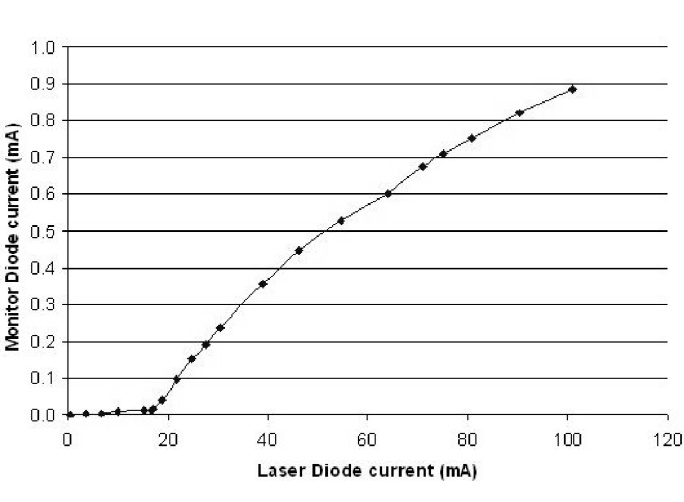


Fig 4: The DC current from the built-in monitor diode vs. laser diode current.

long run it would be likely to take a toll on lifetime.

3.2.2 Modulation of the Laser Diode

We know that transformers are both large and expensive... wrong! An excellent source of HF - UHF transformers are the inexpensive Cable TV power splitters (available here in the U.S. at least) for only a few $ each. Pry off the lid and find the components inside, see Figs 5 - 8

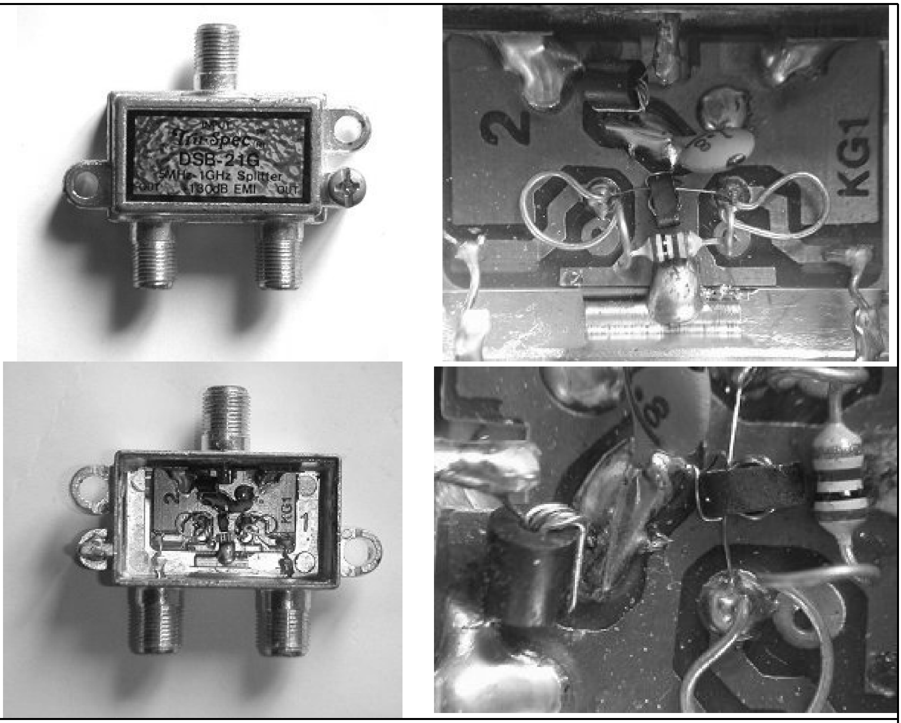
The first transformer, with 2+5 turns, is near perfect for our Laser Diode. It transforms the input signal from 75Ω by $(5/(2+5))^2 = 38\Omega$. This is then split to two 75Ω outputs with the second transformer. A 1.8pF capacitor counteracts some inductive mismatch and the 200Ω resistor, with small inductances on its ends, provides the isolation between the two output ports of the splitter, forming a bridge of sorts, with the 2+2 transformer. This splitter is marked 5MHz ~ 1GHz so one can expect the transformers to be reasonably good over that range.

Unwinding one turn from the five-turn end, makes it a 2+4 turn transformer (Fig 9). Used as an autotransformer the 3:1 turns ratio gives a 9:1 impedance, close to the desired 50:5Ω (Fig 10). These are good little cores and they seem to work fine as marked, from some 5MHz up to almost 1GHz! For lower frequencies one can use a larger core or several small ones, a toroid or a “binocular” core.

Keeping it small, I got excellent results up to, and above, 430MHz, with almost no noticeable degradation of the signal strength as compared to 30 and 50MHz, using a professional, wide band, bias-T on the laser diode. Above 500MHz it seemed to decay, and I do not know if it is due to the emitter or detector, or both. It is more than one can expect from a detector diode with $t_r = t_f < 1$ns anyway.

This circuit is also good for the case where the Laser Diode is remotely located. The DC can be piped in via the same coaxial cable as the signal. One can also use the transformer as a DC choke, but then the matching function is lost.

A simple Bias Tee can be made with a transformer (the 2+2 one for example) connected as a choke and a small capacitor, maybe 220pF. With this the DC and RF can be injected elsewhere and one need only one, slim, coaxial cable to the



Figs 5 - 8: Detail of components inside a power splitter.

Tx (Fig 11 and 12).

A word of warning! Be careful when you connect the Laser Diode to a current limited power supply! It is good to use the variable current limiter (as opposed to the voltage adjustment) to regulate diode bias and to turn it on and off. The power supply must be set to enough voltage, and it is not important how the current limitation will take care of it! Some supplies do not cut the current to zero! If there is only 1mA left, it is enough to charge up the capacitor, 100µF or so, on

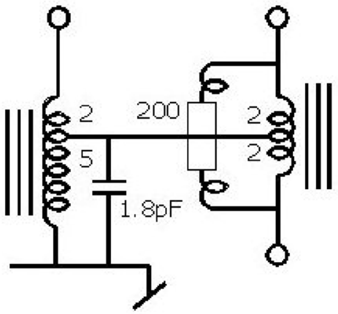


Fig 9: The power splitter.

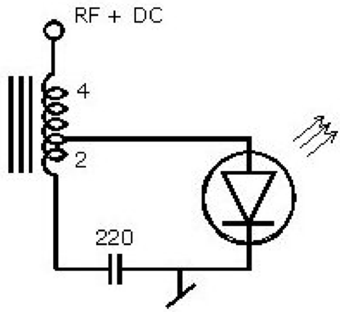


Fig 10: RF modulation of the laser diode.

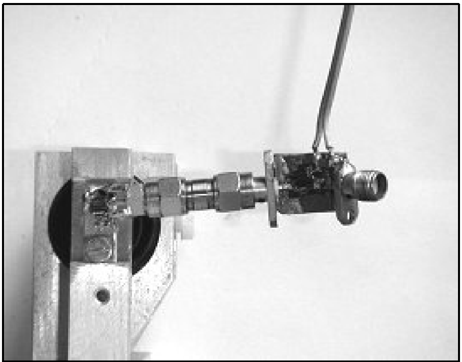


Fig 11: Laser diode with a Bias Tee.

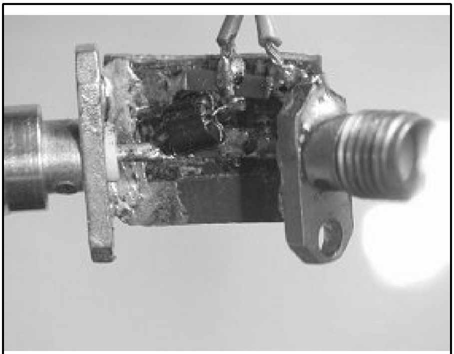


Fig 12: Detail of bias Tee.

the output of the supply. If it is charged up to 3V when you plug in the Laser Diode, you may very well kill it because current limitation is not controlling this capacitor discharge current. So familiarize yourself with your particular supply and find out if it is good enough to turn the current limiter up and down between experiments and if you have to be careful when plugging in Laser Diodes.

3.2.3 Modulation results.

DC bias current and applied RF signals interact in ways that I cannot account for. For given RF amplitude there seem to be a maximum signal (of the detected RF signal strength in the light beam). Unless the signal is strong (>2V into the 3:1 transformer) the ideal DC current is not very large! For my particular diodes there seem to be a maximum around 20mA, just above the threshold value.

I looked into this in three ways:

- Connecting the monitoring diode to an oscilloscope
- Connecting a fast external detector diode to the scope
- Using a large detector diode and the Audio circuit hookup

The first alternative has a few questionable links in the chain of proof. The scope was a 100MHz variety, so it does not do justice to the RF part, but it still seemed to work best around 146MHz. Maybe it is due to my simple Bias-T. When I tried it earlier with the IC R7000 receiver, and a Mini-Circuit Bias-T, I noticed no preference for frequencies; it worked as well at 450MHz as at 30MHz. Anyhow, as I increase the DC bias, the DC output from the monitoring diode increases, as it should. The current from the diode was fed into a 50Ω termination on the scope input. The RF signal was amplitude modulated by 800Hz to 45%, as in all other experiments.

The modulation of the RF was visible, as was the RF signal itself. It came higher on the screen with more biasing, and some distortion of the modulation was clearly visible for some combinations of bias current – RF voltage Figs 13 – 16)

We can see that there is plenty of signal at around 20mA, that at 60mA/0.5V the modulation is fairly clean, but increasing the RF to 1V leads to considerable distortion.

Question is what one should see! The receiver cannot see the 800Hz sine wave in the 20mA/1V picture, but Analog detector can. What would then be the meaning with the RF modulation?

The third alternative employs an "Analog Detector", using a small linear audio amplifier with a detector diode connected

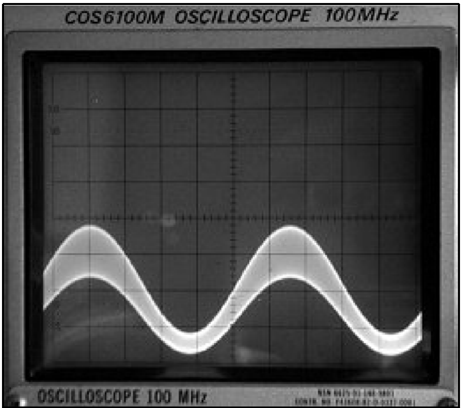


Fig 13: Modulation result with 20mA bias - 1v.

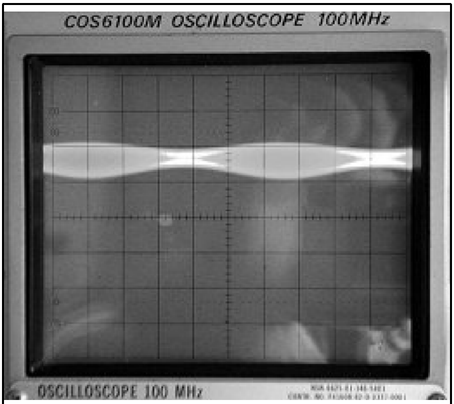


Fig 14: Modulation result RF 60mA - 0.5v.

via an audio transformer, looking at the RF signal with AM as before. The oscilloscope is connected to the collector of one of the output transistors Figs 18 – 22). And the volume control is used for to keep a reasonable signal on the screen. Of course, the RF cannot be seen, and no DC information is lost, the input transformer, the drive transformer and the coupling capacitors on the input and drive stages takes care of that.

The detected signal increases as bias reaches about 20mA.

From the nice signal at 20mA, the signal gets more and more distorted, as well as smaller, as the bias current is increased! At 90mA it is only a second harmonic left. I do not know why this was not reflected in the results from the monitoring diode. Listening to the signal on a radio, there is not doubt that the audible signal, as well as the RF signal strength, peaks around a bias of approximately 20mA. This is certainly worth looking into, and to get familiar with, for your particular Laser Diode setup!

In my tests, beaming a signal to a shopping centre, were carried out with a $1V_{RMS}$ RF signal and I_{DC} bias of 60mA, I was way over the "peak value".

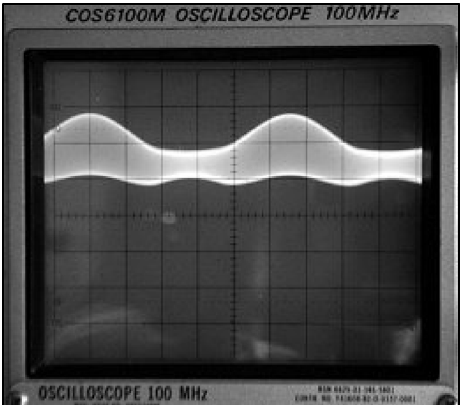


Fig 15: Modulation result RF 60mA - 1v.

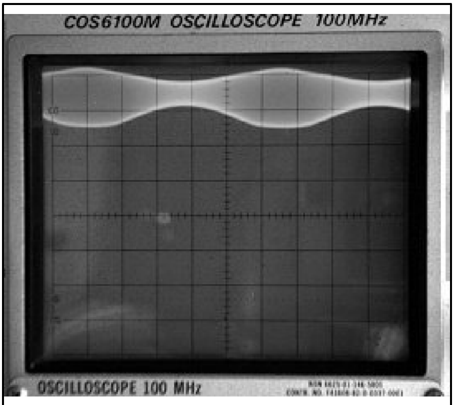


Fig 16: Modulation result RF 90mA - 1v.

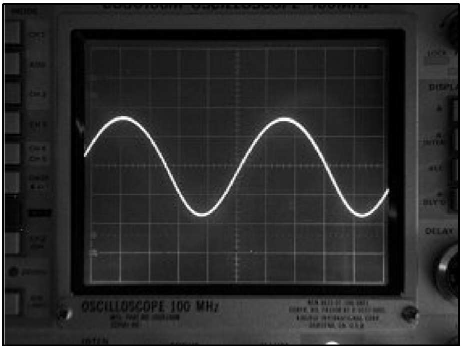


Fig 18: Analogue modulation test 17mA - 1v RF.

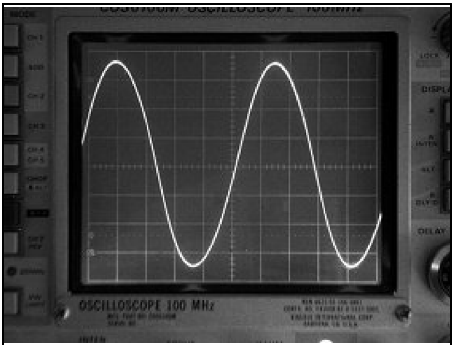


Fig 19: Analogue modulation test 20mA 1v RF.

If the RF is modulating the diode DC current in an otherwise linear area, how can AM on the RF even be detectable by a slow detector? Obviously, the average intensity varies with the 800Hz modulation, so the area is not linear! Maybe that is why the effect is so pronounced around the threshold current.

On the other hand, when observing the S-meter on the receiver the same peaking was clearly visible, but less clear, probably due to the logarithmic nature of the S-meter. There is a peak of about 1 S-unit (it is a lot, 6 dB!) just at the threshold bias current. This has little to do with RF level and the audio modulation. So, for these particular diodes, there seem to be no reason to drive them harder than 20 - 30mA where normal operation is 60 - 70mA.

This is a grey area, and I will have to leave it such, but at least, be advised to look into what bias current works best for you, considering your modulation and

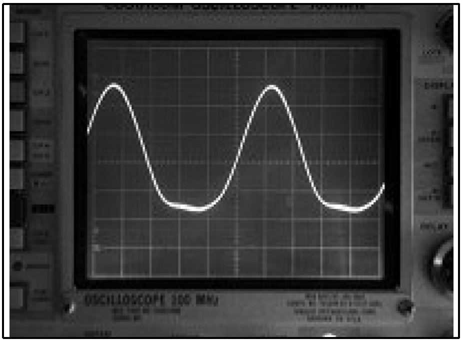


Fig 20: Analogue modulation test 50mA - 1v.

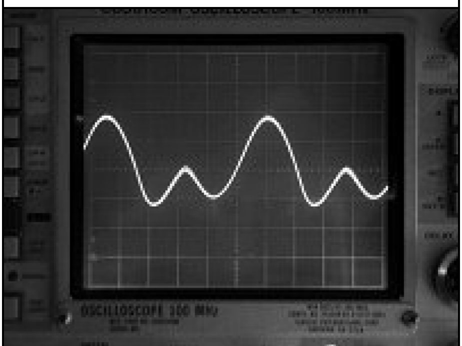


Fig 21: Analogue modulation test 70mA - 1v.

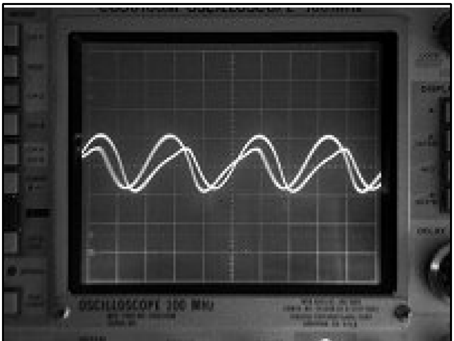


Fig 22: Analogue modulation test 90mA - 1v.

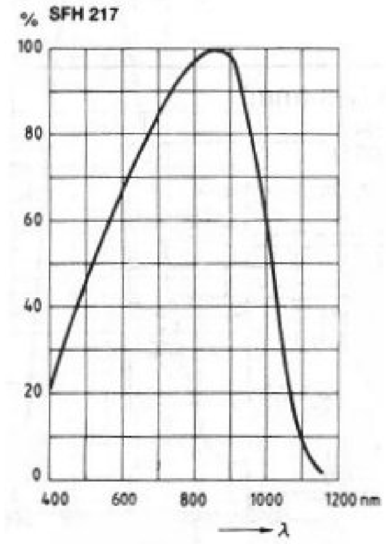


Fig 23: Relative spectral sensitivity of the SFH217 PIN photo diode.

detector/receiver.

3.3 Properties of the PIN photo diode detector

Initially I had the idea of using the built-in monitoring diode of the laser as the detector diode. The light would come in through the same lens as collimated the transmitted signal. Focusing and aiming would then be the same for both Tx and Rx. This did not work very well as the sensitivity was low. Maybe the coating on the Laser Diode chip (that partially blocks the monitoring diode) reflects just its own wavelength?

Fig 23 shows the graph of Relative Spectral Sensitivity (typical for many, if not most, regular PIN photo diodes) we can see that it is well matched to an 830nm emitter and that a 650nm emitter (red Laser Diode or LED) would result in approximately 75% of the signal.

The IR Laser Diode is generally better for this project, than a red light diode, as it probably has more output power and matches the maximum sensitivity of the detector diode. Detectors can have maxima for various wavelengths, as can different Laser Diodes emit various wavelengths. We will soon see how this can be determined, both the wavelength of maximum sensitivity for the detector and the wavelength of the light from the Laser Diode.

So I opted for a separate receiver path. It allows for full duplex communication and the transmitter does not need a very large lens. This may not have been a bad choice anyway, see further discussion under "Properties of the Laser Diode" and about lenses for them.

The detector for the RF modulated light is a silicone photo diode. I found Siemens SFH 217, to be very suitable (Figs 24 and 25). It has a rise and fall time of 1ns (corresponding to f_{t-} = 286MHz) and a square active area of 1mm².

By the way, small, cheap, TV cameras are sensitive to IR light also and can be useful when setting up apparatus! They usually have a filter, blocking IR, which can be removed.

As the optical power (light!) falls on the detector, a current and/or a voltage are generated. If measured with a very high impedance instrument, the voltage U_L is proportional to the logarithm of the illumination. It is in the vicinity of 0.56V for the full Sun, and still over 0.25 for a moderate indoor light. Interesting for exposure meters, but useless for us, as the mode is very slow. The photo diode, like all other diodes, has a junction capacitance and in response to light the diode is a current source of some 0.7A/W. With exceedingly small input power levels, in the pW range, and a capacitance of maybe 10pF, you do the math! We would be lucky to respond to a kHz.

On the other hand, for the shorted diode,

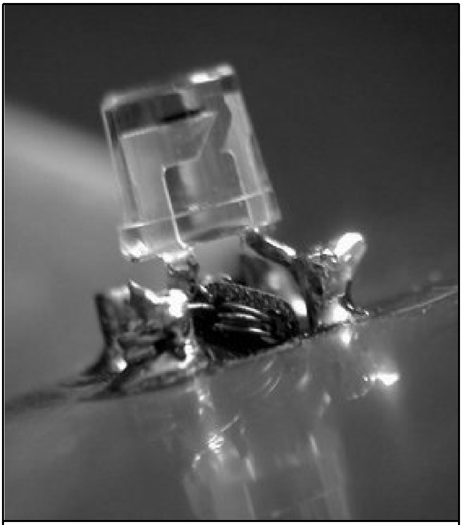


Fig 24: Picture of the SFH217 PIN detector diode.

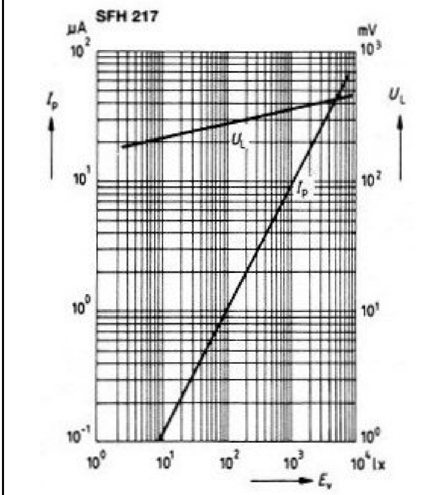


Fig 25: Sensitivity of the SFH217 PIN detector diode.

the output current (A/W) is directly proportional to the illumination (E expressed in W/cm²) and as there is no voltage across a short-circuit; the capacitance is of no concern so the circuit is fast! The proportionality between illumination and current is valid from several Suns down to 0.1 of a full Moon or less. Full Sun is approximately 100,000lux, giving this diode a short circuit current of approximately 1mA. If you measure currents from a photo diode, beware that a 0.1V drop in the meter will begin to give erroneous readings! Switch to the next higher mA-range (lower resistance) and confirm that you read about the same value!

It is common practice to use a Transconductance Amplifier in circuits like this (Fig 26). They have a "short circuited" input as well, due to the negative feedback. But the problem is that they amplify DC (daylight) as well. Besides, one that can handle VHF will hardly compare in sensitivity to the input circuit of a good radio receiver.

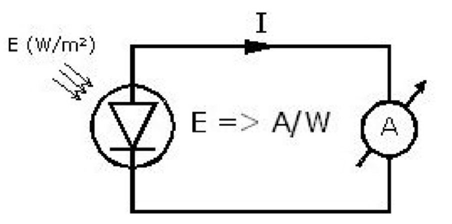


Fig 26: The detector diode function.

For solar blind operation: use an inductor or a transformer on the diode! (Fig 27) This will ensure that the diode is DC-shorted and that only the variations (modulation) of the light are detected. The advantage is that the detector becomes totally solar blind! Not even 2 Suns (the regular one and another one from a mirror) will degrade the sensitivity to RF signals! This sure beats trying to filter out undesirable light with narrowband dichroic ("metal") filters! A narrow band filter may eat 50% of the desired signal, costs a lot of money and will not give solar blindness.

With an inductor across the diode (and the amplifier) one can use a normal, low noise, amplifier for the desired frequency. The AC current, generated by the modulated component in the light, goes through the receiver input imped-

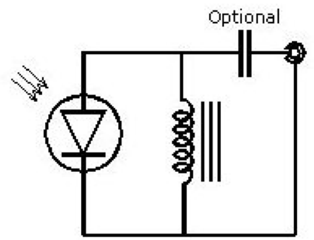


Fig 27: The solar-blind detector diode.

ance (about 50Ω, which is petty much a short for the very small RF currents we are dealing with) and the DC current generated by ambient light is shorted by the inductance to ground. A Bias-Tee used backwards!

When connected to a sensitive receiver (<<1µV) I have heard no contribution from strong light sources like from the Sun or lamps. No noise and no degradation of the desired signal. Even though the 120Hz hum, from lamps, can be strong it will of course not go through an RF transformer, much less be detected by a receiver. If the receiver has a low DC resistance on the input, one can even skip the transformer! But remember that the DC voltage, from constant light sources, must be kept at a minimum, or the diode capacitance will begin to count.

Figuring backwards: my 2m FM radios have 20dB quieting for less than 0.2µV. That corresponds to 4nA into 50Ω, what 1/250,000 of Sun, or some 0.4 lux, Moon light would generate in this small diode!

4.0

Transmitter

For the Laser Diode I use a 25mm lens from an old 8mm projector. At 1km a 3.6 x 9.6µm slot would be magnified 40,000 times to 0.144 x 0.384m. Add a little for the less than perfect lens (although at a single wavelength, as here, lenses become very good!), as well as for a little bit of focusing error, and we can assume a spot the size of ½m at 1km. We would probably not have much use for a smaller spot anyway. Already this one is difficult to aim, and atmospheric disturbances will make it unstable, moving around. At a distance of 1km a 0.3m spot corresponds to an angle of 1 minute of arc, 1/60 degree. This is about half the black on a target at a 300m rifle range. Just a riflescope may be the best device for aiming the laser. Not the least the ability to adjust the hair cross is a great advantage. Anyhow, over the ground, on a sunny day, 1 minute may be all one can hope for. An atmosphere with disturbances of 1 second (1/60 minute) is considered good "seeing" for astronomical purposes and you seldom get it other then when looking up, at stars.

Area of an Ellipse = (π* long axis * short axis) / 4

The area of an elliptic spot of 0.384 x 0.144m is 434cm²

A round spot of 0.5m diameter has 1963cm² or four times more.

At a distance of 1m, without a lens and a 16°x 6° cone, the laser illuminates an ellipse of 0.281 x 0.105m, an area of 232cm².

These conditions can be simulated by operating the laser without lens against the reciever from a distance of

- 1.36m for the perfectly focused case
- 2.91m for the case allowing some focusing and lens errors.

Of course, varying the diode current will vary the power as well and the uneasy atmosphere will not be part of the simulation.

Contrary to some popular beliefs, the anti-reflection coating of the lens has very little detrimental effect on the IR light. I measured with a large area detec-

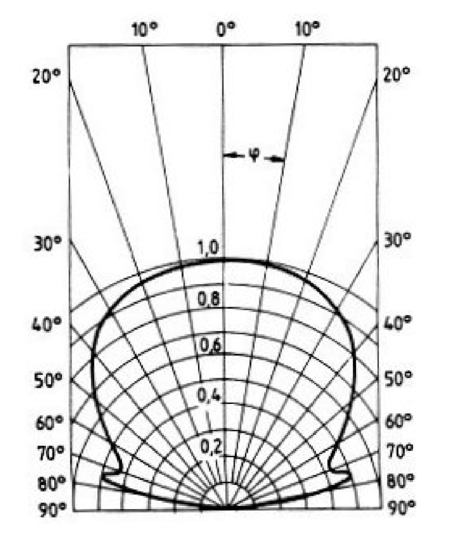


Fig 29: Directional characteristics of the SFH217 diode.

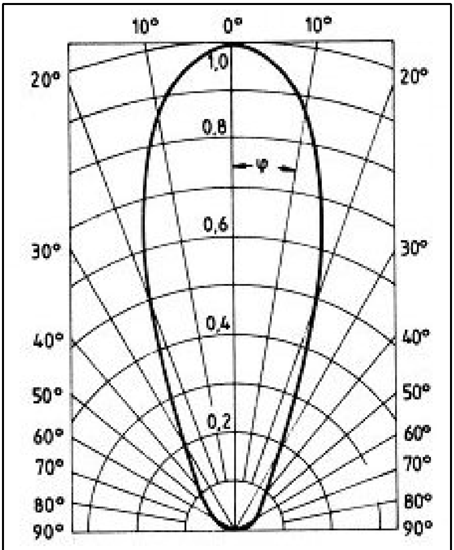


Fig 30: Directional characteristics of the SFH2030 diode.

tor diode current of 58% when focused by my projector lens as opposed to direct with no lens.

5.0

Receiver

Here a larger aperture lens is beneficial. Obviously, a larger area will capture more light. The 55/1.8 lens is still interesting as it is, or ought to be, very inexpensive and reasonable fast. Assuming one (or a second one for the transmitter as well) can be obtained, the SFH 217 (Fig 28) detector, that I use, will not be well covered by such a lens, although it will work. One can put a drop of clear silicone on the diode, forming an extra lens. Naturally one can use a telephoto lens or an astronomical telescope for optics on the receiver. The spot covered would be exceedingly small, but it could be the way to communicate via a reflection form a building, visible from two, or more, points that do not have direct visual contact. This was the original idea behind my work.

Using, for example, a common 8inch Celestron or Meade telescope of Smith Cassegrain type with about 2m focal length, the 1mm² photo diode would "see" 500 x 500mm at 1km. Talk about a Spot Meter. This is on the same order as the spot from the Laser Diode, using the 25mm lens, at the same distance. Telescopes often have good mechanisms to adjust their aim accurately.

A detector with an integral lens package, like a common LED, would be a better choice. Siemens has the SFH 2030 (Fig 29) (and may have others now) with an integral lens and a rise and fall times of 2ns. As I got operation to some 500MHz with the 1ns diode, it is reasonable to assume that this one will do well to 250MHz. It too has a 1mm² detector area. We can see, on the SFH 2030 graph that it will take pretty good care of a light cone of 15.5° to each side. But I happened to have a very fast lens in the junk box. It must have been waiting for an application like this! It is a 50/0.75 where the rear element is only a few mm from

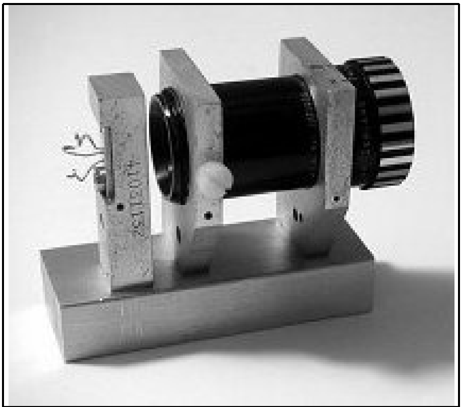


Fig 30 : The laser diode mounted behind a Bolex Paillard 25/1.3 lens. A nylon screw engages a thread on the lens barrel giving convenient focusing by turning the lens barrel as originally intended.

the detector in the focal plane. NA is 0.67 and the half angle 34° so at least a good part of the light will reach the detector element in SFH 217. Maybe I should put a dome of clear silicone on the front of the detector, making it a little more directive, like the SFH2030.

Placing the $1mm^2$ SFH 217 detector behind a 55mm lens will relax the demands for aiming, as compared to using a telescope. Assuming the lens is well focused, we have ±0.5mm on the focal plane, corresponding to an angle of $TAN^{-1}(0.5/55) = 0.52$ degrees or 31 minutes of arc each way, so a total of 1° angle covered. It also corresponds to 9.1m/km, each way, a square of 18m side.

Thus the aiming of such a receiver can be done by simple means, such as a small tube or open "iron sights". If we assume this 55/1.8 lens to be free from transmission losses, it is an improvement of the receiver absorption area from $1mm^2$ to $\pi*30.6^2/4 = 735mm^2$ or a 28.7dB “antenna gain”. This should push an S5 to a few dB above S9.

Fig 31 shows the present apparatus. On the upper left is a small 5X monocular with a built-in hair-cross, for aiming. A riflescope would be better. Below it is the 8mm film projector lens, used for the Laser Diode. It may seem small, but it is all that is needed. On the right is the large 50/0.75 lens in front of the detector diode.

6.0

Practical results

The laser was set up in my lab, aimed out an open window towards a terrace at a shopping centre about 200m distant. The altitude here is ~50m above sea level, resulting in a considerably denser atmosphere than between mountain tops for example. At first we (my sons Philip, Richard and I) could not find the beam. It is IR light and in full daylight we could not even see the source using a binocular (a potentially dangerous manoeuvre). The next evening we added a small monocular with a built-in hair cross to enable the aim. A red vehicle reflector in the back yard made the beam visible to the naked eye so the monocular could be adjusted to coincide. We tried the beam the same night and got a good signal, about 6½ on the S-meter, which is pretty good on the IC-R7000. Then I got the idea to put the signal generator on AM and modulate with a 800Hz tone AM to 45%. Next day, in full daylight (bright overcast) we got up on the terrace again and could clearly hear the modulated signal. This time we got S5 at best, I do not know why, but I am quite sure that the daylight had nothing to do with it.

Fig 32 shows Philip holding a plate with the small ($1mm^2$) photodiode connected directly to the receiver antenna input. Richard is trying to get a glimpse of the laser through the binoculars, but he is outside the beam. Philip holds the detector diode in the maximum.

With a diode current of 60mA DC, an RF

Fig 31: The present apparatus.

signal of 1Vrms at 145.5MHz (through the 4+2 transformer, Z=9:1) AM 800Hz 45% we got an S5 and a tone that sounded very frail! (Audio file: AMsound1.wav on the VHF Communications web site).

The "frailty" of the sound is probably due to scattering of the light in the hot daytime air. With a detector as small as $1mm^2$, the "pipe" for the detected light is in a cone that is some 200m long, 1mm at one end and 25/1.3 = 19mm at the Laser end. Of the about 50 x 100mm at the received end, most of the light is lost. Only approximately 1/4000 hits the detector! The same effect that makes stars seem to twinkle (as they are point-shaped sources), called "speckle", will occur here.

Fig 32: Carl's sons taking part in tests.

A lens would of course create a stronger signal, and I think it may also defeat some the speckle and the frail sound. The $1mm^2$ detector, without a lens or focusing mirror, is not considered a practical solution, it is merely my "worst case" test. If it works, as it did, then there is a lot of margin with a lens (or a reflector) onto the detector diode, an obvious and simple arrangement.

Trying FM (at 145.5MHz) as opposed to AM, gave a better result for the sound quality. The sound was much cleaner, even though the signal strength for some reason was down to only a few S units. The test had to be carried out with an ICOM IC-24, in low power position, as the signal source, with a 20dB attenuator on the output. The initial power should have been some 300 – 600mW so after the attenuator, 3 - 6mW or 10 - 13dBm. The 1V RF signal used in earlier tests corresponds to 13dBm. The same 60mA DC bias current to the diode was used in this experiment as well. The FM modulation is naturally less sensitive to amplitude variations, and the sound quality was a lot better in spite of the weaker RF signal, almost good. Speech could easily have been understood. (Sound files: FM 12s and FM 8s on the VHF Communications web site).

I tried holding a small lens, an eye loupe, in front of the detector diode while using the "Analogue Detector" and it was difficult to aim, holding on to everything, but when I momentarily hit the right direction the signal got very strong, but the sound quality of the tone was still "frail". FM, or CW, seems to be the way to go. A Bias current of 20mA would have resulted in a much better signal.

7.0

Conclusions

Although the initial goals of communicating via reflections from clouds and buildings were not achieved, a multitude of practical results and observations were had. They can be used for many applications, besides Amateur Radio, such as security installations, short data links between buildings, secure garage door openers and the like:

- The concept of using ham equipment directly (without sub carrier) for modulation and detection of the beam on a solar-blind link for VHF to UHF, at the least to 70cm, and at any type of modulation, has been introduced and tried. HF should be absolutely no problems.
- A general familiarisation with some optical terms, including a description of how to measure wavelengths and spectra of light by simple means. Enough information to make a useable monochromator at a very low cost will be described in part 2.
- The concept of solar blind detectors, allowing for a much simplified apparatus compared to a detector with dichroic filters (that would not make it really solar blind anyway), and a way to match a Laser Diode to a 50 transmission line, has been described.

Perhaps one could say that, from Alexander Graham Bell's point of view, the circle just has come all the way around. Today one can take, and send, photographs with telephones.

In Part 2 more optical terms and a monochromator using a CD as a diffraction grating will be discussed.

8.0

References

[1] LA6NCA site about The Lichtfernsprecher:

http://www.laud.no/la6nca/radio/german/german1/lispr.htm

http://www.laud.no/la6nca/radio/german/german1/lispr2.htm

[2] http://home.t-online.de/home/hhcuno/index/htm

[3] http://www.qsl.net/wb9ajz/laser/laser.htm

Alexander Meier, DG6RBP

Design and realisation of a coaxial low pass filter for 1.85GHz

In contrast to stripline filters, coaxial filters have a very low insertion loss, together with a high degree of stop-band attenuation over a wide frequency range. They are thus eminently suitable for use for measurements, or at the output of a final stage. This article shows how a coaxial low pass filter for a spectrum analyser with a cutoff frequency of 1.85GHz can be designed and built.

1
Introduction

Heavy demands are made on the input filter of a spectrum analyser, in particular on the filter attenuation in the image frequency range. A typical analyser up to 1.8GHz uses a 2.2 - 4GHz YIG oscillator as a local oscillator, and has a first intermediate frequency of 2.2GHz. This gives an image frequency range of 4.4GHz to 6.2GHz, which should be suppressed by at least 80 to 100dB. In addition, the filter in the pass band – i.e. from 10MHz to 1,800MHz – should display only slight insertion loss (< 0.5dB). A coaxial low pass filter can meet these demands best.

2
Principles

As can be deduced from the name, coaxial low pass filters consist of a periodic sequence of coaxial lines of various lengths and with alternating impedances. A short line section with a thick internal conductor has a low impedance, Z_C, and represents a capacitor, whereas a thin internal conductor has a high impedance, Z_L, and thus represents an inductance. Fig. 1 shows the mechanical structure of a coaxial low pass filter. In this case, it is a cylindrical internal conductor with varying diameters, which is incorporated into a metal sleeve as an external conductor. Fig. 2 shows the associated equivalent circuit diagram for the low pass filter.

3
Calculation of component values

A Chebyshev function was selected for the design of the coaxial low pass filter.

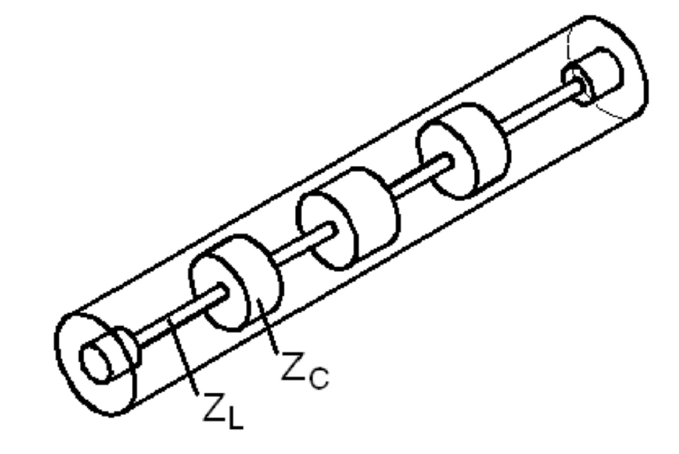


Fig 1: Mechanical layout of the low pass filter.

Here the attenuation in the pass band oscillates around a constant value with a uniform oscillation amplitude (ripple). The cutoff frequency is the one at which the attenuation exceeds the maximum ripple value for the first time.

The following design parameters have been set for the filter:

- Cutoff frequency: 1.85GHz
- Attenuation in pass band: < 0.3dB
- Return loss in pass band: > 20dB
- Attenuation above 4GHz: > 80dB

The filter quality and therefore the order n of the filter can be estimated on the basis of these details to be bigger than eight. This order equals the number of elements required – i.e. the inductances and capacitors.

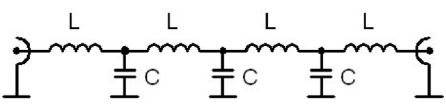


Fig 2: Equivalent circuit diagram for the low pass filter (here n=7).

To make the mechanical structure of the filter symmetrical – i.e. with equivalent elements at the beginning and end of the filter – an odd number order, for example n = 9, is required. In order to obtain the desired standard of filter design in practice, with a safety margin, the filter order is, in the end, fixed as the next highest odd number order, n = 11.

Thus the standardised filter elements, g, which represent the capacitors, together with the source impedance (g_0) and the loaded impedance (g_{n+1}), can be calculated using the familiar formulae for the Chebychev approximation. Then they are converted to the filter impedance (Z_Q = 50 Ohms) and the desired cutoff frequency f_0 = 1.85GHz. This gives us the component values for the inductances and capacitors.

The filter was designed to start and end with an inductance. So we obtain:

L_1 = 3.17nH, L_8 = 7.55nH, L_5 = 8.16nH
L_7 = 8.16nH, L_9 = 7.55nH, L_{11} = 3.17nH

C_2 = 2.42pF, C_4 = 3.00pF, C_6 = 3.08pF
C_8 = 3.00pF, C_{10} = 2.42pF

The index for the component designations corresponds to the eleven mechanical sections of the filter.

4

Calculation of mechanical dimensions of filter

The necessary length for the line sections are now calculated using these component values. To do this, we first lay down the line impedances from the mechanical standpoint. You are recommended to select a capacitor impedance, Z_C, of < 30 Ohms and an impedance for the inductances, Z_L, of > 130 Ohms. In addition, Teflon rings should be inserted between the internal and outer conductors on the line sections of the capacitors. Thus the internal conductors are centred and the filter is more stable mechanically.

As regards the filter, a diameter of 0.5mm was selected for the thin internal conductor, and a diameter of 6.3mm for the thick internal conductor. The outer conductor was fixed at 8mm. Teflon rings were provided between the thick internal conductor and the outer conductor. This gave an impedance, Z_L, of 165 Ohms, Z_C being 10 Ohms. Once the line impedances are fixed, the necessary length dimensions still have to be calculated from the component values. The procedure required for this can be found in [1]. First the mechanical lengths of the inductances are estimated:

$$l_n = \frac{C_0}{\omega_C} \cdot \arcsin\left(\frac{\omega_C \cdot L_n}{Z_L}\right) \quad n = 1,3,5..n \ (1)$$

c_0 = speed of light (300,000km/s)

$\omega_C = 2\pi f_C$ (f_C = cutoff frequency)

L_n = inductance

Z_n = impedance of inductance line sections

We obtain:

$l_1 = l_{11}$ = 5.8mm, $l_3 = l_9$ = 14.4mm, $l_5 = l_7$ = 15.7mm

Owing to the cross-section jump at the line section transition from the capacitors to the inductances, an additional capacitance arises, the fringing capacitance. The value of this capacitance can be determined from diagrams, e.g. in [1, p. 203]. Otherwise it is set at zero, but this leads to a less accurate result. In our case, there is a capacitance, C_f, of 0.181pF for the cross-section jump with the selected mechanical dimensions.

Thus, with the start values of (1), the lengths of the capacitance line sections can now be calculated:

$$l_n = \frac{Z_C \cdot c_o}{\omega_C \cdot \sqrt{\varepsilon_{rc}}} \cdot \left[\omega_C \cdot C_n - \frac{\omega_C}{2 \cdot c_0 \cdot Z_L}(l_{n-1} + l_{n+1}) - 2 \cdot C_f \cdot \omega_C\right]$$

n = 2,4,6...n-1 (2)

ε_{rC} = relative permittivity for capacitor line sections (here: Teflon 2.2)

C_f = fringing capacitance owing to cross-section jump between Z_C and Z_L

For the capacitance line section lengths, we obtain:

$l_2 = l_{10}$ = 3.8mm, $l_4 = l_8$ = 4.7mm, l_6 = 4.9 mm.

Next, the precise inductance line section length dimensions are calculated:

$$l_n = \frac{c_0}{\omega_C} \cdot \arcsin\left[\frac{\omega_C \cdot L_n}{Z_L} - \frac{Z_C \cdot \omega_C \cdot \sqrt{\varepsilon_{rC}}}{2 \cdot c_0 \cdot Z_L} \cdot (l_{n-1} + l_{n+1})\right] \quad (3)$$

n = 1, 3, 5...n (for n = 1, l_{n-1} is set at zero)

We obtain:

$l_1 = l_{11}$ = 5.6mm, $l_3 = l_9$ = 13.3mm, $l_5 = l_7$ = 14.4mm

Thus all mechanical dimensions for the filter structure are calculated.

When the filter is assembled, the first and last inductances are connected to a con-

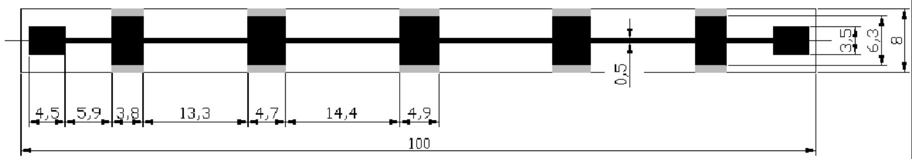


Fig 3: Sketch with the measurements of the symmetrical filter design. The two 4.5mm sections at the input and output of the filter connect to 50Ω SMA connectors.

nection socket (e.g. SMA) by means of a short 50 Ohm line.

If we know the fringing capacitance, C_{10}, for the cross-section jump at the transition between the 50 Ohm line (Z_0) and the line which represents the inductance L_1 or L_{11}, then the first and last lines, l_1 and l_{11}, must be extended by the value for l_0:

$$l_0 = Z_0^2 \left(\frac{C_{f0} \cdot c_0}{Z_L \cdot \sqrt{\varepsilon_{rC}}} + \frac{l_1}{2 \cdot Z_L^2} \right) \qquad (4)$$

At the transition from the 50 Ohm line, with a diameter of 3.5mm, to the inductance, with a length of 5.6mm, a fringing capacitance arises, C_{10}, of 0.023 pF, and thus an extension, l_0, of 0.3mm. The length of the line section for l_1 and l_{11} is thus 5.9mm.

Before the filter can be mechanically assembled, the question arises about the frequency to which it will be usable. This can be estimated. The frequency at which the longest line section displays an electrical length of half a wavelength, the filter attenuation breaks down once more! The mechanical length of the inductance line sections can be shortened if we make the ratio between the internal and external conductors bigger. But the filter is mechanically more difficult to realise with a thin internal conductor. For the dimensions calculated, the longest line amounts to l_5, l_7 = 14.4mm. That means that the filter attenuation breaks down at a frequency of 10.4GHz.

We also have to avoid the occurrence of waveguide modes in the pass band and stop band due to excessively large diameters for the internal and external conductors. The first higher waveguide mode, H_{11}, arises, with the diameters selected for internal and external conductors, at a frequency of 9GHz. It should thus be possible to use the filter in the frequency range up to approximately 10GHz.

5

Realisation of the coaxial filter

First a sketch is prepared marked with all the dimensions (Fig. 3). Then the individual sections can be made on a lathe. Since it is extremely difficult to create the filter in one piece, it is recommended that only the line sections of the capacitors should be cut off. To do this, first turn the raw material to a diameter of 6.3mm and bore through to 0.5mm in the middle. Then cut off the line sections of the capacitors in accordance with the sketch (Fig. 3) with the lengths required. Then pin them on a brass rod (or wire), which forms the inductance, at the correct intervals and solder them. The 50 Ohm transitions are likewise cut off on the lathe. These have a continuous bore of 0.5mm, which is bored on one side

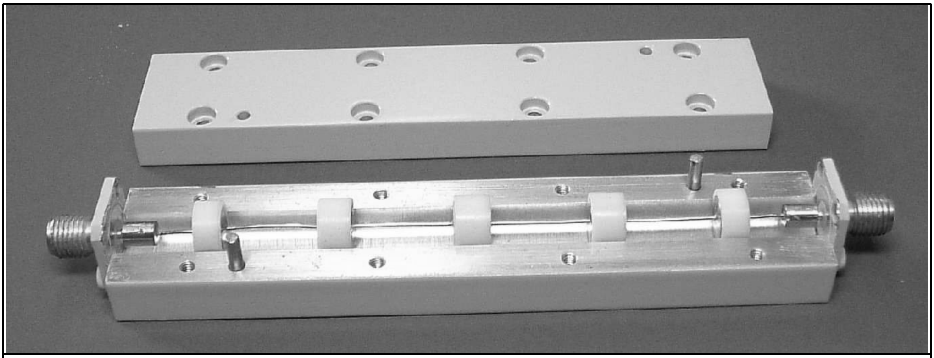


Fig 4: The prototype low pass filter.

with the diameter of the internal conductor of the SMA socket. Now the transition pieces are soldered to the ends of the filter. Finally, the Teflon rings are made on a lathe and pushed onto the capacitors. There are two possible options for incorporating the filter into the filter housing as an external conductor:

- Bore through the face of a square bar on the lathe to the external conductor diameter and insert the filter into the bore created. The connector sockets can now no longer be soldered on. You are recommended to slit the 50 Ohm transition piece sideways, so that the internal conductor of the SMA socket creates a plug-in connection to the filter when the filter is assembled. This only works if the filter structure is stable with a sufficiently thick internal conductor.

- Divide the square bar into two halves and screw the two halves together on the external sides. Then bore all the way through both sections on a lathe. The advantage is that both halves can be dismantled at any time. Thus the filter can be put into a shell, aligned and soldered to the SMA socket. This procedure was selected for the prototype of the 1.85GHz low pass. Figs. 4 and 5 show the prototype.

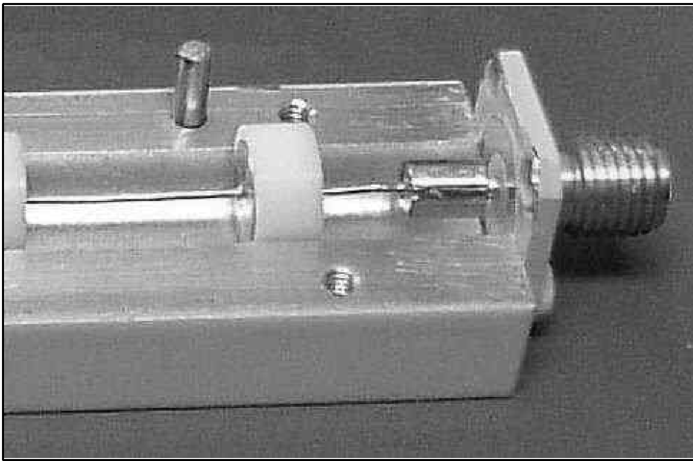


Fig 5: Close-up view of an end of the prototype low pass filter.

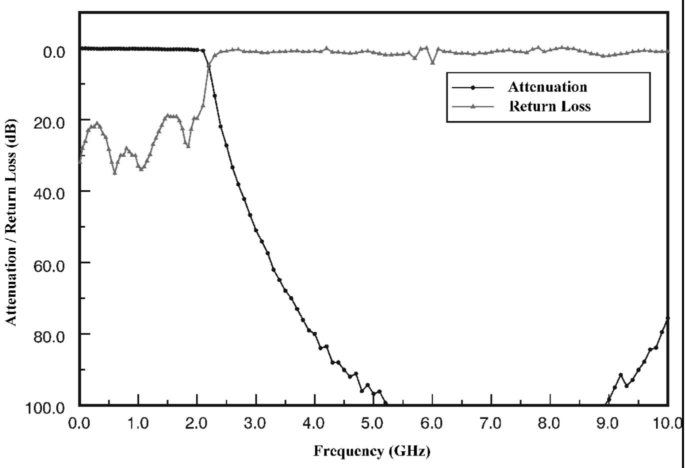


Fig 6: Attenuation and Return Loss of the 1.85GHz low pass filter.

6
Measurement results

Since coaxial low pass filters display a very high level of stop band attenuation, this measurement requires a correspondingly high accuracy. For this reason, the low pass filter was inserted between an RF signal generator and a spectrum analyser during the measurements and the attenuation was determined point by point. A thermal output meter was used instead of the spectrum analyser for the measurement of the low insertion loss. Then the graph curve was plotted using "SciGraphica" [2].

Fig. 6 shows the filter's return loss. The cutoff frequency lies just above 1.85GHz. In the stop band, an attenuation of 80dB is obtained at a frequency of 4GHz. It has therefore turned out to be a good idea to select the filter level somewhat higher than would be necessary in accordance with the estimate for the filter requirement. With the level of eight initially estimated, the design values for the filter design (80dB attenuation at 4GHz) would not have been attained.

At a frequency of 5.3GHz, the attenuation exceeds 100dB. Owing to the length of the inductance line sections, the attenuation falls off again at 9GHz. If the frequency response is measured again (Fig. 7) up to 20GHz, points where the attenuation has collapsed can clearly be seen and can be attributed to the individual line sections. This confirms the assumptions made at the design stage.

Fig. 6 shows the filter's return loss. In the pass band, the values do not fall below the required level of 20dB. Fig. 8 shows the insertion loss of the filter. In the pass band, up to 1.85GHz, it is a maximum of 0.33dB, which is only slightly bigger than the design parameter.

The filter thus fulfils the requirements laid down for an input filter for a 1.8GHz spectrum analyser that is being developed. The characteristics plotted in relation to insertion loss and filter attenuation justify the high expenditure on the mechanical realisation.

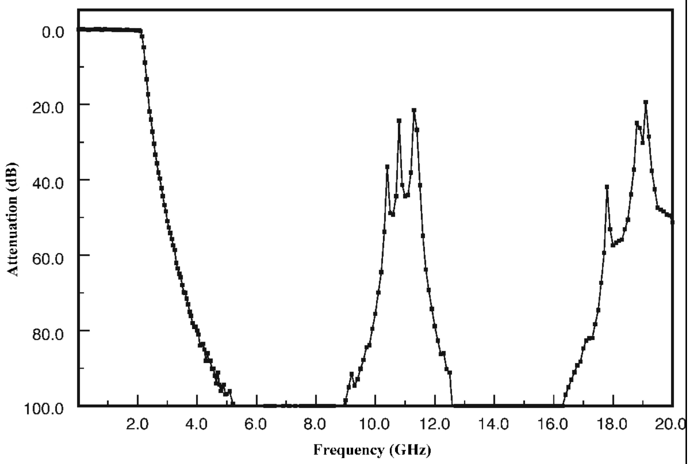


Fig 7: Frequency response of the low pass filter plotted up to 20GHz.

7 Literature

[1] Matthaei, Young, Jones Microwave Filters, Impedance-Matching Networks, And Coupling Structures Artech House Inc (1980)

[2] SciGraphica, Webpage http://scigraphica.sourceforge.net

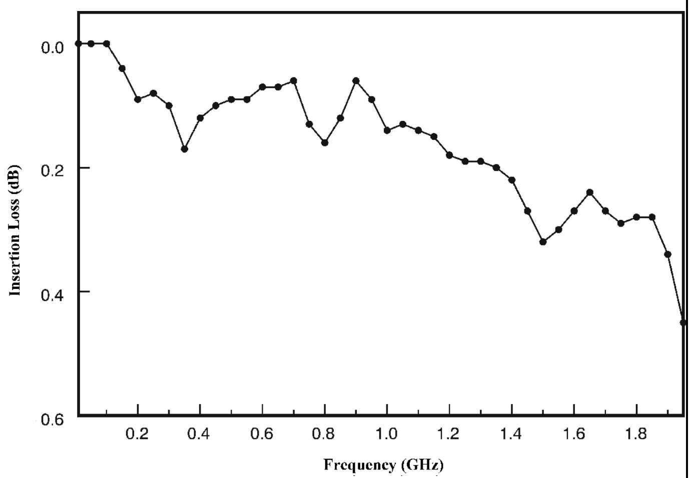


Fig 8: Insertion loss of the low pass filter plotted from 0 to 1.85GHz.

Bernd Kaa, DG4RBF

A simple approach to YIG oscillators

YIG oscillators have been in use for several decades now, mainly in relation to equipment for professionals from well-known manufacturers. However, we radio amateurs have been prohibited from enjoying their outstanding characteristics for many years, owing to the high prices involved. But for some years now, YIG oscillators have been obtainable at reasonable prices on the surplus market. Most of the equipment available has already been taken out of service, but this poses no problems as a rule, since YIG oscillators have a very long service life and are of excellent quality. This article is intended to provide some practical help regarding a simple approach to these high-quality oscillators.

1

Advantages of YIG oscillators

YIG oscillators have some advantages over normal VCO's. It is above all their good signal quality, with a low level of phase jitter, and their broad band characteristics (with a very linear tuning curve) which make them interesting, or even obligatory, for many measurement applications. Anyone who has become acquainted with the advantages of these oscillators will no longer want to do without them.

The normal frequency ranges are 2 - 4GHz, 4 - 8GHz, 8 - 12GHz, 12 - 18GHz and 2 - 8GHz. However, the usable frequency range usually goes beyond the specified limit frequencies, so that a YIG which is specified for 2 - 4GHz can be used at 1.8 or 1.9GHz, and can frequently also still function at a few 100MHz above 4GHz, but this varies from type to type.

2

YIG resonator

Fig. 1 shows the core of a YIG oscillator. The YIG ball, which sits at the tip of a short ceramic rod, is positioned in the middle of a coupling coil (U bolt). This YIG resonator is influenced by the magnetic field that is generated by the tuning coils. This allows the YIG to be tuned to its frequency.

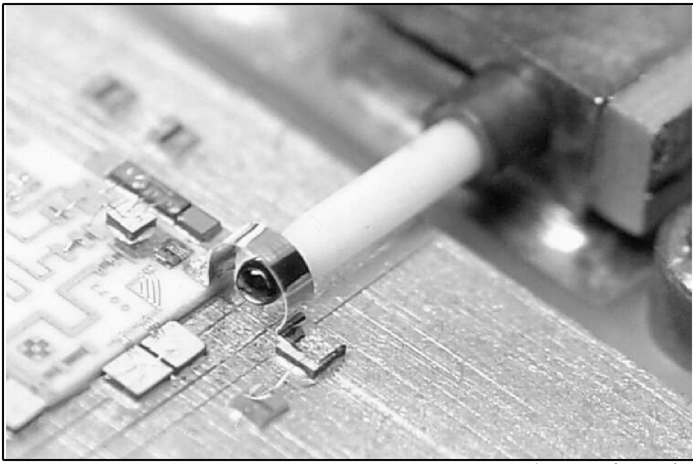


Fig 1: The core of a YIG oscillator.

3

YIG oscillator connections

The connections of a YIG oscillator are shown in the circuit. They have a standard pin configuration, which is almost always the same (Fig. 2).

3.1 Operating voltage

These "standard YIG's" always require + 15V(approximately 150 - 300mA) and frequently also – 5V as operating voltages. But there are also some manufacturers who depart from this norm, and their YIG oscillators need completely different voltages. For example, Hewlett Packard, whose YIG's frequently need + 20.5V and – 5.1V, or + 20V and – 10V.

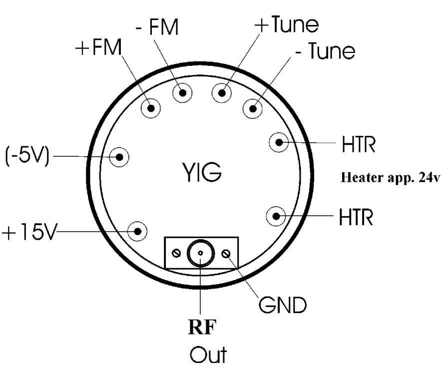


Fig 2: The standard pin connections for a YIG oscillator.

There are also oscillators from Watkin-J that require a negative operating voltage of – 14.2V. But the good thing about this is that these voltage specifications are almost always printed on the oscillator. Fig. 3 shows three YIG's with + 15V and – 5V as operating voltages. Fig. 4 shows three examples from different manufacturers with an operating voltage of + 15V alone. In spite of differences in shape and size, the "standard" pin configuration has been retained.

3.2 Heating

There are usually two connections for heating. These lead to a small PTC plate inside the oscillator, which serves to keep the YIG element at a uniform temperature. The voltage for heating is not critical, and is normally about 24V. A relatively high starting current of several hundred mA falls off markedly after a few seconds, and then oscillates around a value of < 100mA. Fig. 5 shows a small heating plate of this kind on the YIG ball

Fig 3 Examples of YIG oscillators with operating voltages of +15v and -5v.

mounting.

3.3 Main tuning coil

The main tuning coil is usually indicated by "+ tune" and "– tune". In contrast to a VCO, where the frequency is controlled using a tuning voltage, a YIG is "current controlled" i.e. the frequency of the YIG oscillator depends on the current which flows through the tuning coil. The great thing about this is that the frequency response curve is very linear in relation to the current fed in. 20MHz/mA is a typical value.

The main tuning coil consists of thick enamelled copper wire and is very powerful. Even currents exceeding 1A can be coped with for a short time. Incidentally, the tuning current should always be fed in to the correct pin. This coil's resistance is approximately 10Ω, but it can lie in a range between 5 and 15Ω. The thick main tuning coil can easily be recognised in Fig. 6. It runs around the metal plate

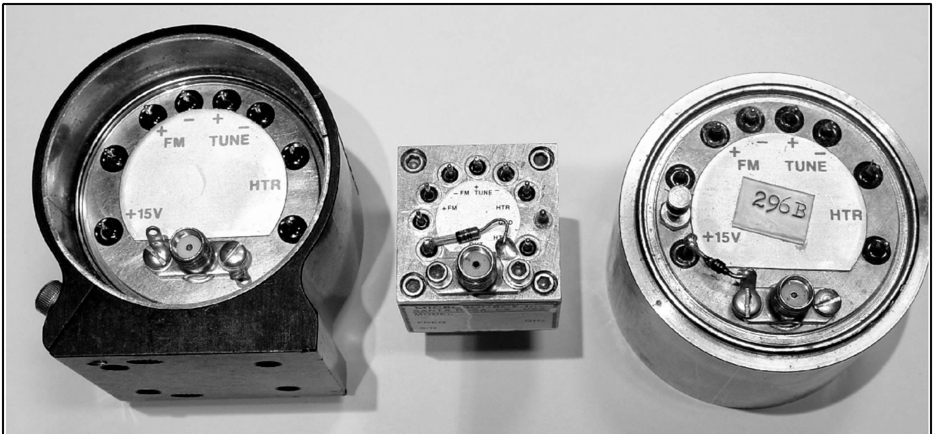


Fig 4: Examples of YIG oscillators with operating voltages of +15v.

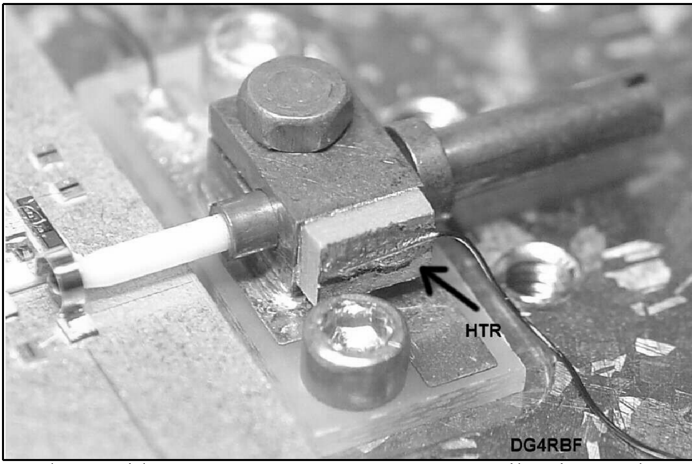


Fig 5: The PTC heating plate in a YIG oscillator.

on the outside.

3.3 FM coil

A second tuning coil is used for fine tuning or the FM modulation of the oscillator. It is indicated by "+ FM" and "– FM".

This small coil consists of very thin wire, has a resistance of only approximately 1Ω, and could be destroyed by currents exceeding 200mA. So care must be exercised here.

The small coil on the plate is the FM coil and can be seen in the middle of Fig. 6. But there are also models without an FM coil. Fig. 7 shows a unit of this type. Although this YIG has no connections for the FM coil, the other pins correspond to the standard layout.

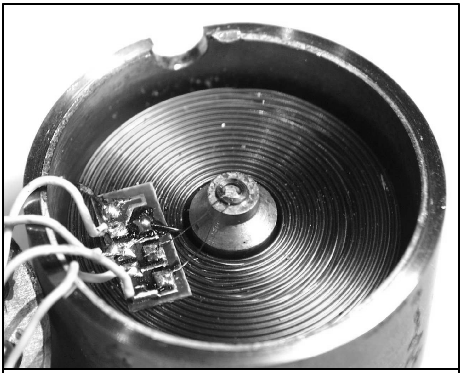


Fig 6: The tuning coils.

So there's no need to be scared of YIG oscillators! Using them is really quite simple and not critical. If you have a YIG that has the connections laid out in the circuit as described, everything is really clear, even if the pins are not labelled. As a precaution, you can check the connections for the two tuning coils with an ohmmeter. Zener diodes are frequently fitted as a protection against an over voltage on the pins caused by the operating voltages.

Care must be exercised with YIG oscillators from HP, as most have unlabelled connections which do not correspond to the "standard" and often also need decidedly unusual voltages. The connections here should be known, or you should obtain a connection diagram. Figs. 8 and 9 show two examples from Hewlett Packard.

3.4 Output of YIG oscillators

The output to be expected lies in the range between + 10dBm and + 15dBm. For many examples, it can even extend to + 20dBm. Depending on the frequency range, the output can vary by a few dB's.

Fig 7: A YIG oscillator with no FM mode.

Fig 8: An example of a HP YIG oscillator with non standard operating voltages.

4

Simple putting into operation of YIG oscillators

What's a simple way of putting a YIG oscillator into operation?

Fig 9: Another example of an HP YIG oscillator.

A mW meter with a suitable attenuator, or better, a spectrum analyser, is connected to the RF output. After feeding in the correct operating voltage, connect an adjustable power supply (approximately 0 – 20V / 1A) via an output resistance (Fig. 10).

Then slowly increase the tuning current until a measurable signal level is obtained at the output (lower frequency limit). Carry on increasing the current until the output signal fades again. This is the upper frequency limit of the oscillator. The operating range can therefore be determined using a frequency counter.

It should be taken into account that this frequency limit is somewhat dependent on temperature. So heating should be connected up if possible. It should also be taken into account that a considerable tuning current sometimes has to flow through oscillators for relatively high frequencies before oscillation sets in. Thus, for example, in a YIG which is specified for up to 18GHz, 420mA is already flowing through the main tuning coil before it begins to operate at approximately 8GHz.

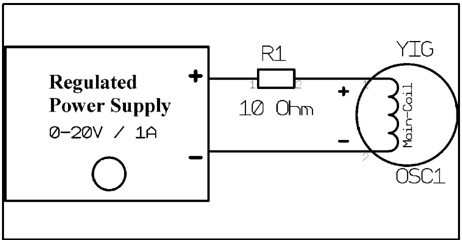


Fig 10: Circuit for operating a YIG oscillator.

4.1 Triggering of YIG oscillators

To be able to trigger a YIG at a voltage, you need a YIG driver, a voltage/current transformer. An appropriately wired operational amplifier with an output transistor normally carries out this task. A suitable circuit can be seen in [1].

5
Other models

Square format units can also pop up. Figs. 11 and 12 show two specimens of this type. Luckily, the connections are mostly labelled here as well.

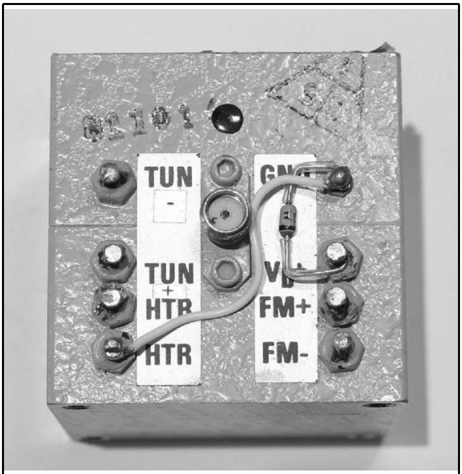


Fig 11: An example of a square format YIG oscillator.

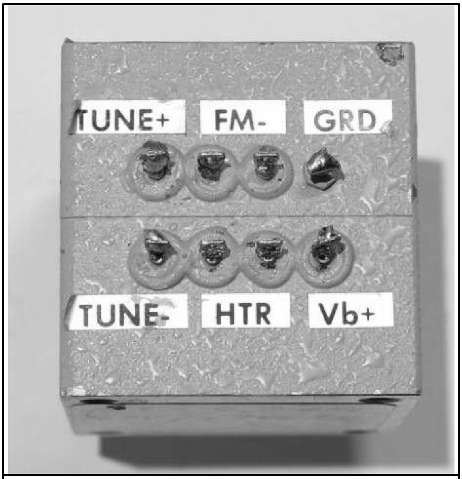


Fig 12: A second example of a square format YIG oscillator.

5.1 YIG oscillators with integrated driver

There are also types of equipment that already incorporate the YIG driver. Figs. 13 and 14 show oscillators like this. These are then usually tuned with a tuning voltage of between 0 and 10V. A connection diagram should acquired for these types, since no rules are applicable here. Finally, I'd like to mention two other types, although they are rare.

Fig 13: An example of a YIG oscillator with built in YIG driver.

Fig 14: A second example of a YIG oscillator with a built in driver.

Fig 15: An example of a YIG oscillator requiring variable operating voltages.

5.2 YIG oscillators with variable operating voltage

In these types, the operating voltage must also be varied if they are to be able to operate in all possible frequency ranges.

Here, for example, is an oscillator for 8.0 – 12.0GHz, which has an operating voltage of 15.5 – 9.7V. At the lowest frequency of 8.0GHz, an operating voltage of 15.5V should be set, and at the highest frequency of 12.0GHz the operating voltage should be only 9.7V. So for these types the operating voltage must be altered inversely to the tuning current. But it can also suffice to switch the operating voltage in two ranges. Thus this oscillator can be operated at 15.5V from 8 to 10GHz and at 10.5V from 10 to 12GHz. Fig. 15 shows this oscillator.

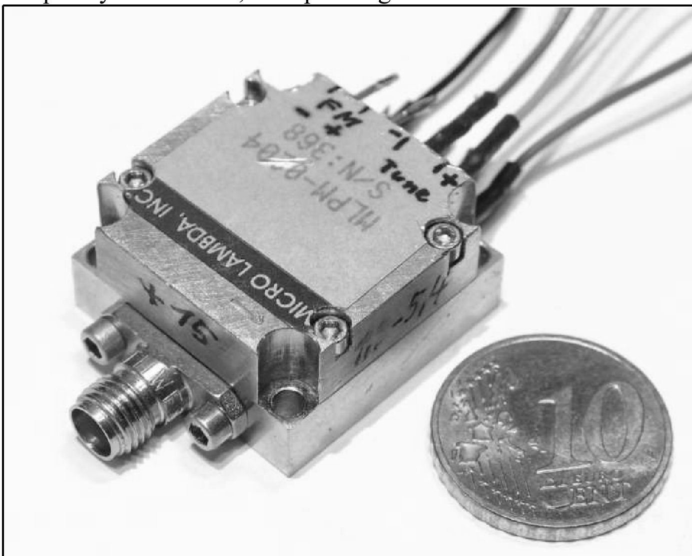


Fig 16: An example of o YIG oscillator with a permanent magnet.

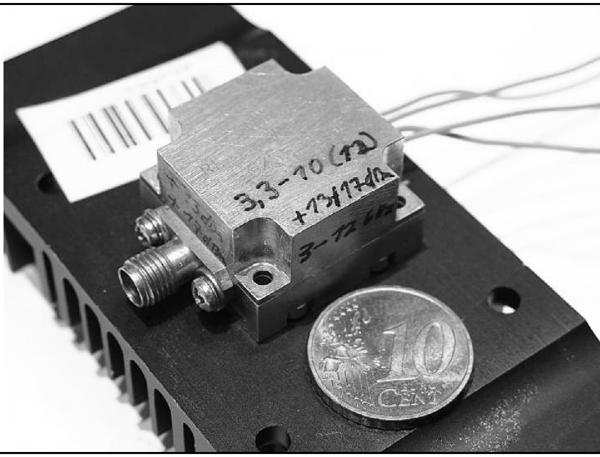


Fig 17: An example of a miniature YIG oscillator that operates up to 10GHz.

5.3 YIG oscillators with permanent magnet

YIG oscillators with permanent magnets represent a decidedly special and very recent development. These YIG's oscillate even without a tuning current, and they do this at their centre frequency, the "free run frequency".

Thus a YIG for 2 - 4GHz operates at 3GHz and can, depending on the polarity of the tuning current, be tuned to 1GHz up or down. Fig. 16 shows such an oscillator.

6

Cooling

However strange the idea may seem at first, a YIG should be heated and cooled. Heated so that the YIG pellet reaches its operating temperature rapidly, and cooled so that the heat building up in the main tuning coil can be used to heat the YIG up really well. Cooling is necessary, above all, at relatively high operating frequencies, since here there can be a considerable current of up to 1A, and so a considerable heat loss is generated.

Fig. 17 shows a miniature YIG oscillator, which operates at up to 10GHz and becomes very hot. This YIG was experimentally mounted on this heat sink, but it was somewhat too small.

7

Conclusion

I couldn't find much on the Internet on the subject of YIG oscillators and their connections. So I just hope that these remarks (without a lot of theory) help to make it easier to use these interesting components.

8

Literature references

[1] Synthesiser signal generator for 10 to 1,800MHz Bernd Kaa, DG4RBF, VHF Communications 2/2004 pp 66 – 94.

Hubertus Rathke, DC1OP

A Uni(versal) counter up to 12GHz

The idea for the design of this Uni(versal) counter was crystallised by the publication of an article about the divide by 1000 12GHz prescaler by Alexander Meier in [1]. The form of words in the title is intended to refer to the fact that in operation some restrictions will have to be taken into account regarding the accuracy of display. These are due to the possibility of error considered in [1], and also to the counting procedure used with the PIC. However, the result is an easy-to-use frequency counter, in particular for SHF and UHF applications, and there is also the option of acquiring data on the low frequency ranges, and all this for a thoroughly reasonable cost.

1

Functional description

The Uni(versal) counter consists of the following function units (Fig. 2):

amplifier up to approximately 50MHz (for input 1)

- 1.3GHz divide by 64 prescaler (for input 2)
- 12GHz divide by 1000 prescaler (for input 3)
- Measurement input changeover with U_B supply
- PIC counter with LC display
- Power supply

The core of the unit is the PIC counter, with a single line sixteen character LCD display to show the frequency for each of the three inputs, together with the measurement range. Seven characters are displayed on each range, but they are not always all used. The representation on the LCD display is shown below, with the leading zeroes suppressed:

- Input 1: --1 0 , 1 2 3 MHz
- Input 2: 1 0 1 2 , 3 4 5 MHz
- Input 3: --1 0 , 1 2 3 GHz

In front of the PIC counter is a changeover switch, which switches both the measurement signal and the individually associated operating voltage, corresponding to the selected measurement range and the pre-amplifiers/amplifier module, through to the counter input. This excludes any influence on the measurement signal by crosstalk in the electronic signal switching path, and the current consumption is kept to a minimum.

Fig 1: Picture of the completed Uni(versal) counter.

A preamplifier that increases the signal to be measured to the TTL level suffices for the "low-frequency" input 1. The PIV counter input is a schmitt trigger input for the TTL level, which can process signals up to approximately 50MHz.

The "middle-frequency" input 2 covers a frequency range of approximately 50MHz to 1.4GHz. With a divide by 64 prescaler, a frequency of approximately 22MHz is obtained to be processed by the PIC, and is then multiplied by 64 for the display.

Input 3, with the divide by 1000 12GHz prescaler by, reliably covers this frequency range down to approximately 500MHz. An input frequency of 10GHz, after being divided by 1,000, corresponds to an output frequency of 10MHz, which is processed directly by the PIC. When this input is used, only the frequency display on the LCD display is switched from MHz to GHz.

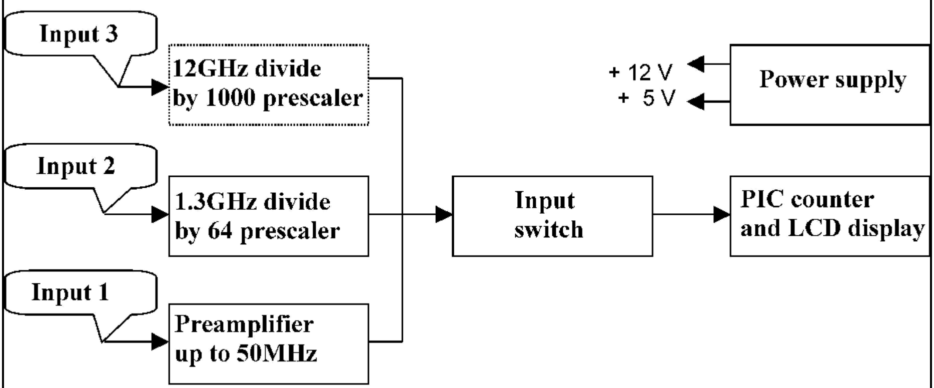


Fig 2: Block diagram of the Uni(versal) counter.

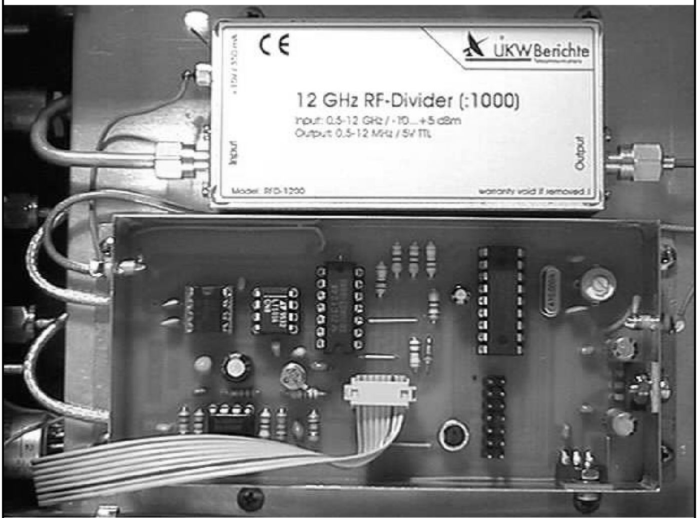


Fig 3: Picture of the prototype Uni(versal) counter showing the 12GHz prescaler and the main counter PCB in its tinplate housing.

Two amply sized voltage regulators (5V and 12V) are provided for the power supply, so that the counter, including the 12GHz prescaler, can be operated with an unregulated DC voltage of >13.5V.

The input sensitivity values for each input represented in the diagram (Fig. 4) were attained on the Uni(versal) counter prototype (Fig. 3).

The measurements were carried out using 6dB compulsory matching at 50Ω, with -30dBm being fixed as the lower measurement limit.

1.1 Input voltage limits:

Now for the upper input voltage limits of inputs 1 to 3:

Alexander Meier specifies a maximum input power of 5dBm for the 12GHz prescaler, which corresponds to a voltage of 400mV at 50Ω. This value is not changed by integration into the existing circuit.

The U893 prescaler used for input 2, is specified by the IC manufacturer for approximately 300mV at the IC input as the upper, guaranteed function limit for the input voltage. This is just 3dBm at 50Ω. In the context of the measurements referred to above, the input was also experimentally triggered at 5dBm (400mV), which had no functional effect.

The input voltage level at input 1 is relatively uncritical, it processes any level up to 500mV (7dBm). In addition, owing to the limiter characteristic of the amplifier, harmonics may be generated, which can be recognised because the display will continually change.

As shown on the input sensitivity diagram, it is clear that this value decreases sharply from about 30MHz for input 1. This is caused by the internal divider factor of the PIC set by the software, which influences both the upper measurement frequency and the maximum error for the basic display. But this also means that the PIC's capacity to count signals up to 50MHz is relinquished in favour of a lower error deviation.

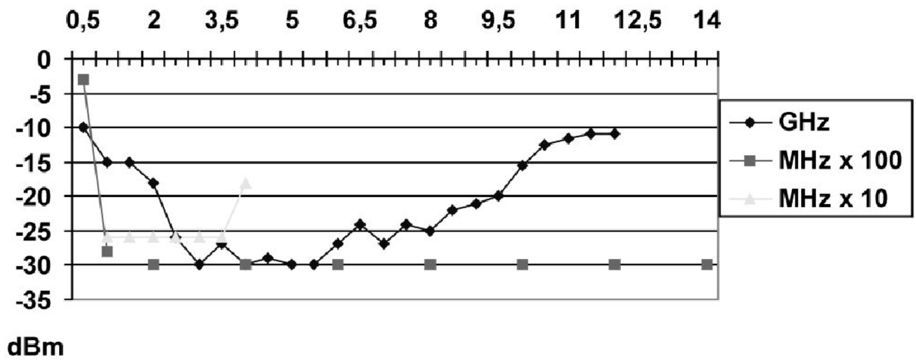


Fig 4: The input sensitivity of the Uni(versal) counter.

2
Circuit description

All function units described above (up to the 12GHz precaler) are mounted on a large printed circuit board, approximately 54 x 109mm. Fig. 5 shows the complete circuit.

The external measurement inputs are connected by means of coax cable. The LCD display and the input changeover are connected using a flat ribbon cable using header plugs. The LCD display, connection has no cross overs and should be securely fixed in the plugs.

The sketch in Fig. 6 gives a guide for wiring of the range changing switch.

The memory function of the 16F84-20/P PIC is not needed here, it is just used as the counter. Owing to the system architecture of the PIC, pin RA4 is used as the counter input. The diode connected to +5V is intended to protect the input against input signal overvoltages. The pins RA0 and RA1 are defined as control inputs for changing over the display and the display multiplier. The 16 character single line LCD display (16 x 1) is driven from pins RB0 to RB7.

An analogue switch – type OD74HCT4066 – is used as the changeover switch for the signal path. In the "off" state, its control inputs are earthed, in order to prevent the inputs oscillating and creating feedback. The control inputs are selected using one wafer of the 2 x 3 switch on the front plate. The second wafer is used to changeover the operating voltage required.

The TL592 video amplifier is used as the pre-amplifier for input 1. It requires no frequency compensation and has a 3dB bandwidth that is typically 50MHz. The PIC is triggered by means of a direct-voltage coupled emitter follower.

A type U893B divider does its work in input 2. This component, originally developed as a preamplifier for satellite tuners, is very sensitive, but, in accordance with its target application, tends to oscillate if there is no input signal. A fast

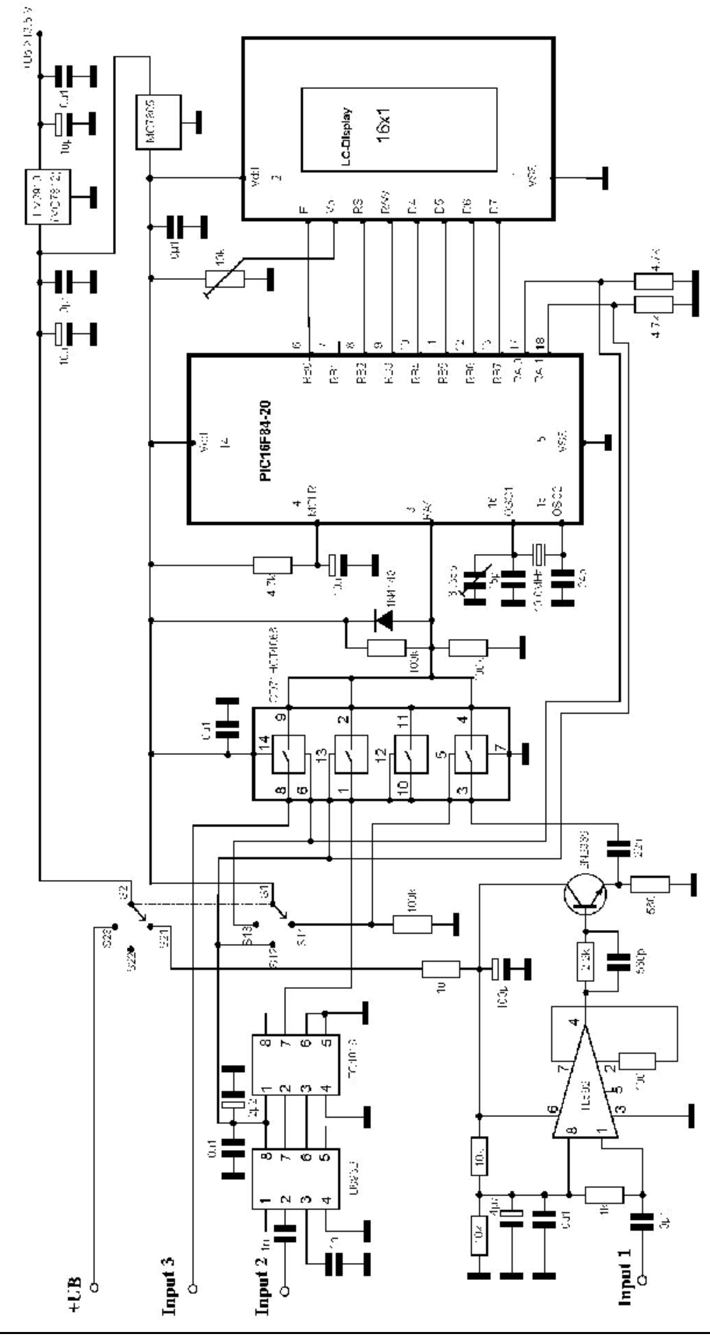


Fig 5 Circuit diagram of the Uni(versal) counter.

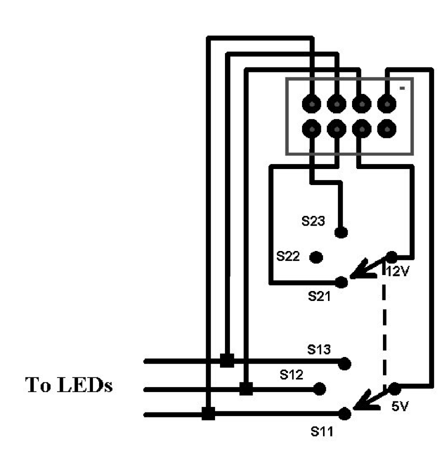


Fig 6: Switch connections.

comparator (LT1016) generates a TTL compatible signal from the differential output signal of the divider to trigger the PIC.

Input 3 is the GHz input. The signal, divided by 1,000, is fed to the PIC directly as a TTL signal through the analogue switch.

3

Software functions

The signal to be counted at pin RA4 is transferred by means of a divider, inside the PIC, to the timer 0, which counts the incoming pulses over a fixed measurement period. This results in a binary number that is converted into a decimal number and transferred to the intelligent LCD display for output.

If there are external pre-dividers, like the divide by 64, the numerical result must be multiplied again by the divider factor before the display. Likewise, the internal divider factor is taken into account if it is activated. The calculation is carried out using 32 bits, and 7 decimal characters are output.

The external pre-divider (divider by 64) is also changed over, together with the display range in the LCD display, using pins RA0 and RA1, by means of software.

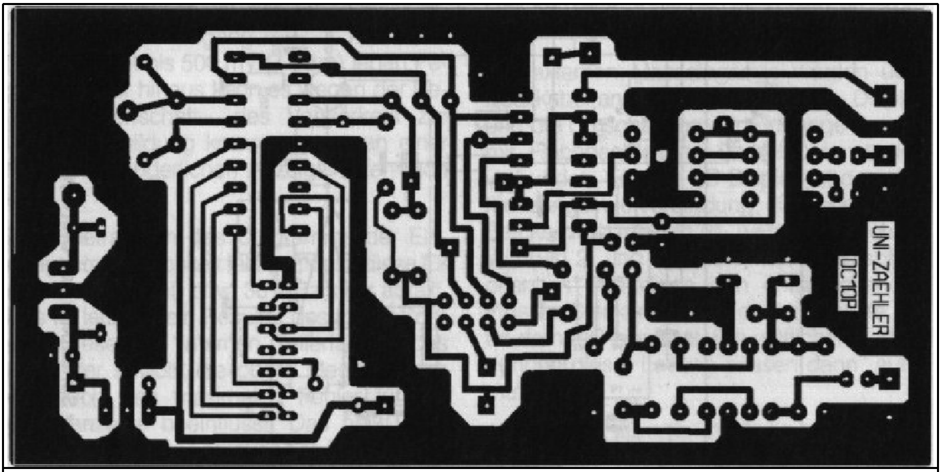


Fig 7: PCB layout for the Uni(versal) counter.

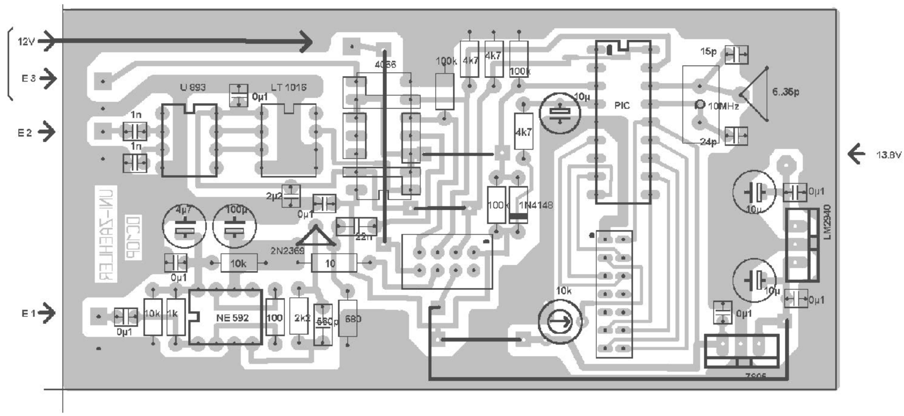


Fig 8: Component layout for the Uni(versal) counter.

4

Allowance for error

Using the selected solution, if the loop calculations inside the PIC are used and taken into account, a maximum error of 32Hz can arise for the basic display – i.e. if the external pre-dividers are not taken into account. These increase the deviation once more by the divider factor. In the case of the divider by 1,000, the display may deviate by up to 32kHz.

Another factor causing the numerical figure to deviate from the actual value present is the PIC's quartz oscillator. This oscillator generates the PIC's calculation cycle, but simultaneously also generates the measurement period window for the timer 0. This means that the oscillator should be adjusted as precisely as possible to the rated frequency 10,000.0xx MHz. As was demonstrated using the prototype, this undertaking is not all that easy using normal computer quartzes.

5

Assembly and operation

Before the components are mounted on the board, it is soldered into a tinplate frame (or housing), which also acts as a cooling surface for the voltage regulator.

In the prototype, all the IC's were in very high quality sockets, but as a minimum the PIC should have a socket. Once the components had been carefully mounted and the necessary external connections had been made, the counter was ready to operate.

The display contrast was adjusted using the 10kΩ potentiometer on the LCD display.

There are two options for setting the quartz frequency. The quartz signal is monitored using a suitably calibrated receiver and adjusted (SSB range). Or a calibrated frequency – e.g. 10MHz – is fed into input 1 and the quartz then adjusts itself to the counter display.

As regards operation, it should be pointed out that the input level should be increased until a stable display is obtained. The exception to this is the last digit in each case if the digit in front of it (but not displayed) becomes too high.

5.1 Uni counter parts list

Semi-conductors:

1 x LM 2940 (low drop, alternative MC 7812 CT)
1 x MC 7805 CT
1 x LCD matrix display, 16 x 1 (Anag Vison)
1 x PIC 16F84A-20/P
1 x 1N4148 or similar Si diode
1 x CD 74HCT4066
1 x TL 592
1 x 2N2369
1 x U893B
1 x LTC1016

Resistors:

1 x 10Ω
1 x 100Ω
1 x 56Ω
1 x 1kΩ
1 x 2.2kΩ
3 x 4.7kΩ
2 x 10kΩ
3 x 100kΩ
1 x 10kΩ potentiometer

Capacitors:

1 x 15pF
1 x 24pF
1 x 6.3 pF trimmer
1 x 560pF
2 x 1nF
1 x 22nF
7 x 100nF
1 x 2.2µF
1 x 4.7µF
3 x 10µF
1 x 100µF

Miscellaneous:

1 10,000MHz quartz
1 2 x 7 strip connector
1 2 x 4 strip connector
Tinplate frame or suitable tinplate housing
Flat strip cable
2 x 7, 2 x 4 and 1 x 14 pins for LCD display, 2 x 3 switches

6 Summary

As already explained in the introduction, a frequency counter can be created (with relatively little expenditure on hardware) which displays a calculable tolerance in the measurement ranges which, in individual cases and if necessary, can be corrected by means of simple calculation. The software solution handles the counting procedure itself and the display.

7 Literature

[1] Alexander Meier, DG6RBP 12GHz Divide By 1000 Prescaler, VHF Communications, 4/2003, pp. 199 - 206

Wolfgang Schneider: DJ8ES

Intermodulation behaviour of hybrid amplifier modules

So-called hybrid amplifier modules have existed for some years – e.g. those made by Mitsubishi or Toshiba. These modules are also available for the amateur radio bands between 6m and 23cm. Standard types offer high outputs of up to 50W for input levels in the mW range, and a supply voltage in a range of 12 to 14V.

Unfortunately, this does not get us very far with the linearity required, e.g. for SSB mode, in connection with the spectrum purity of the output signal. This article is intended to provide an outline of this question. All measurements relating to intermodulation behaviour and harmonic content are carried out on a 2m PA using an M57727 hybrid module. The manufacturer specifies a maximum output of 37W for this component, with an input level of only 300mW.

The PA module (with a downstream 2 circuit band pass filter) has already been described some time ago [1].

1
The PA module

The circuit diagram of the power amplifier for 144MHz can be seen in Fig. 2. The circuit's core is an M57727 hybrid module from Mitsubishi (IC1). Such amplifier modules are constructed using thick film technology. The amplification specified in the data sheet – specifically intended for the frequency range between 144 and 148MHz – is obtained using a two-stage circuit. The expenditure required on the external circuit is only minimal.

A downstream low pass filter provides the necessary harmonic reduction. This is a so-called peaked low pass. Better values can be obtained in relation to the edge steepness than with the classic low pass filter circuit, using only two PI filters interconnected via a coupling capacitor.

Fig. 3 gives a diagrammatic representation of the gain slope (continuous line). The dotted line shows the linear path (theoretical only) for determining the 1dB or 3dB compression points. The last one lies at + 39.5dBm (approximately 10W), which corresponds to the maximum output in only about a quarter of the manufacturers' specifications referred to initially!

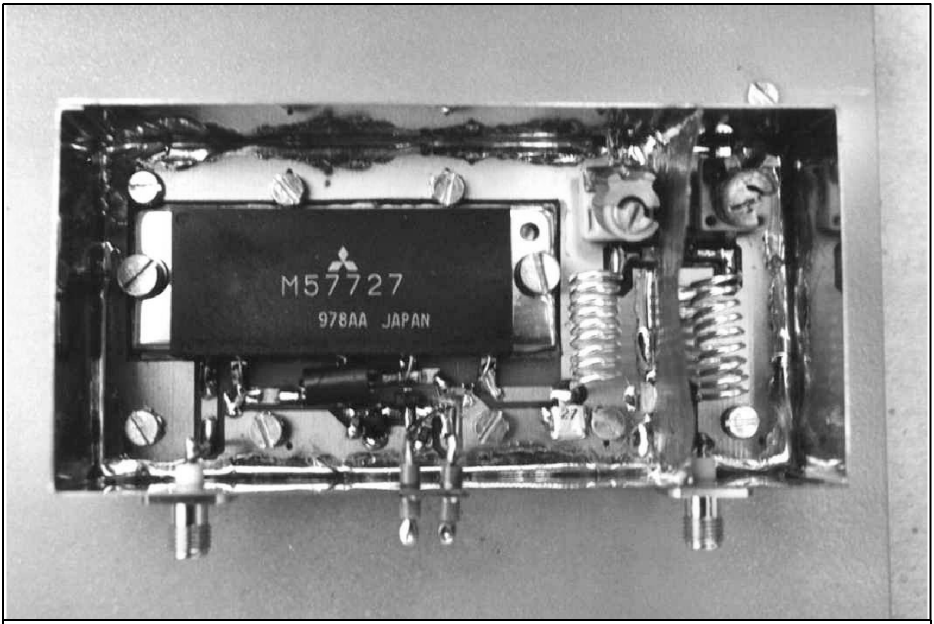


Fig 1: 2m PA with hybrid amplifier and 2-stage output filter.

2
The 2-tone generator

Two signals of equal strength, frequencies f_1 and f_2, are fed into the input of this stage to measure the intermodulation behaviour. Depending on the quality, the amplifier produces a more or less distinct spectrum of intermodulation products from this. The most important, as regards practical applications, are the values for the third order ($2*f_1 - f_2$, $2*f_2 - f_1$) and

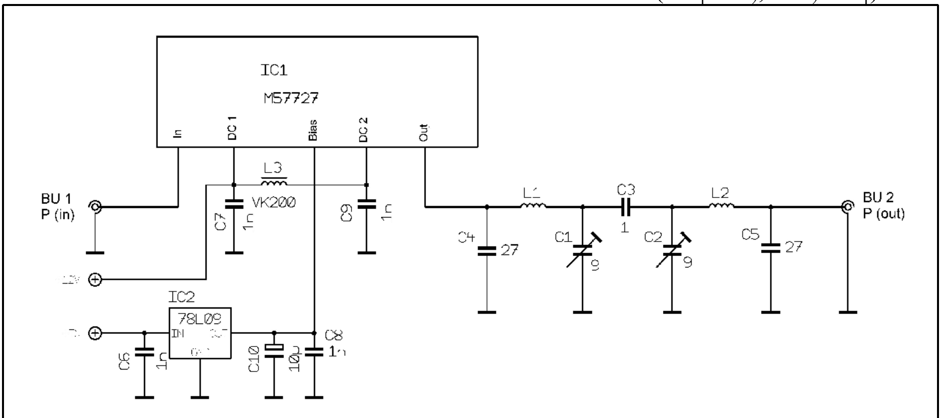


Fig 2: Circuit diagram of the 2m PA.

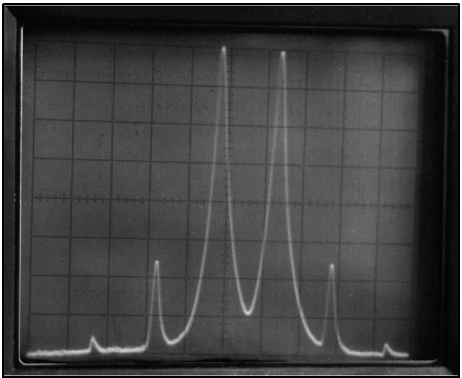


Fig 3:2-tone signal at 2 x 10mW (40mW PEP).

fifth order ($3*f_1 - 2*f_2$, $3*f_2 - 2*f_1$). The aim is to obtain third order intermodulation products of less than -30dB for SSB amplifiers, based on the pure tone. If no attention is paid to these quality criteria, an SSB transmitter will have a wide signal and poor modulation quality.

To make it possible to measure the intermodulation products, the corresponding 2-tone generator must already be providing a high-quality signal itself. The equipment used here [2] meets this requirement completely. Fig. 3 shows the signal spectrum of the hybrid amplifier. The output level is +1 dBm (10mV) per pure tone.

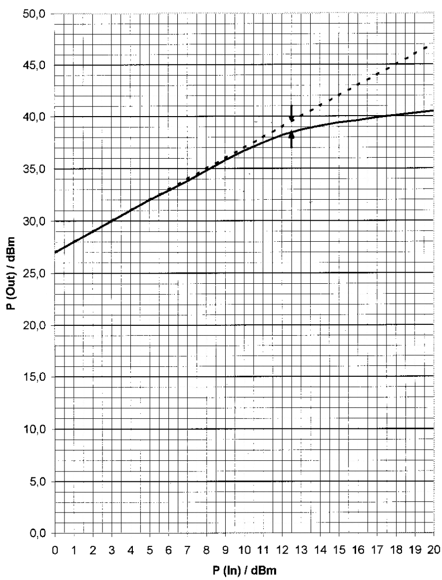


Fig 4: Gain slope of the 2m PA using an M57727 hybrid amplifier.

If a higher output level is required, a suitable output amplifier can be connected to the 2-tone generator. As the measurements below demonstrate, however, there is simply no question of this with regard to hybrid amplifier modules.

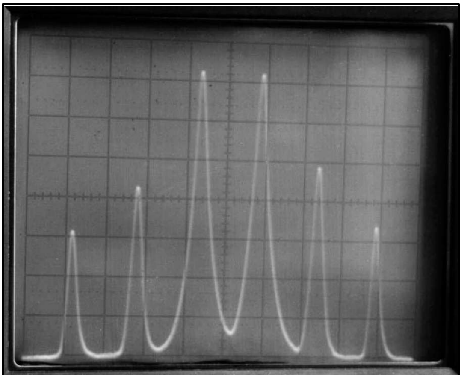


Fig 5: IM products -24dBc with a 40mW PEP 2-tone signal input.

3

The intermodulation behaviour of the hybrid amplifier module

When fed by the 2-tone generator, the high-level stage module amplifies the output signal from an M57727 amplifier module by approximately 26dB.

The gain slope (Fig. 4) makes it clear that the 1dB compression point of the PA is

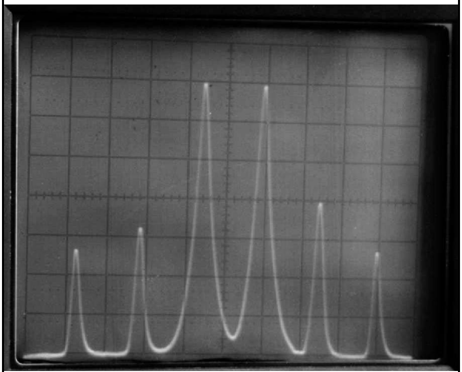


Fig 6: IM products 130dBc.

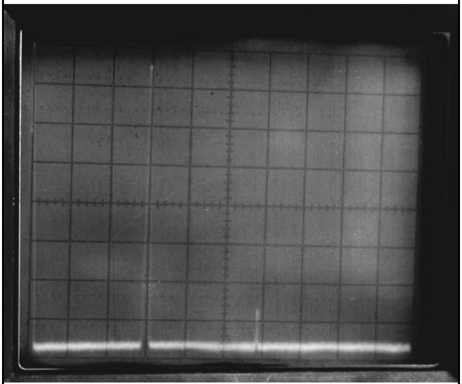


Fig 7:Harmonics suppressed by more than 60dBc using filter.

obtained just exactly at this level. i.e., the signal starts to distort and the harmonic content – in the form of intermodulation products – increases at a disproportionate rate. The IM interval at this point is -24dBc (see Fig. 5).

With an input only 3dB lower, the intermodulation products are immediately reduced by as much as 6dB (Fig. 6), i.e. twice as much. Unfortunately, this effect applies in reverse as well!

As the input level falls, and thus the output is continually reduced, the intermodulation behaviour thus becomes better and better. Thus, for example, the hybrid PA has a very clean output signal (IM_3 < 48dBc) at an output level of 100mV. Though to talk in terms of a PA here is no longer appropriate.

Finally, here too we must look for a healthy compromise. This seems to lie at the 1dB compression point already referred to above. The value of the IM products of -24dBc is thoroughly acceptable for practical operation.

4

The harmonic spectrum

A 2-circuit band filter is connected to the output of the amplifier module. This takes the form of a peaked low pass.

A harmonic suppression exceeding 60dB is obtained using this layout (Fig. 7). The third harmonic in the 70cm band is no longer detectable using the given methods of measurement. For the sake of interest, the behaviour of a downstream filter was also investigated. A value of only -26dBc is obtained for the second harmonic (Fig. 8). The interfering signals visible in the spectrum in the lower frequency range result from the loose coupling of the spectrum analyser. The decidedly modest values in relation to the suppression of the harmonics make any discussion regarding the necessity for the output filter superfluous.

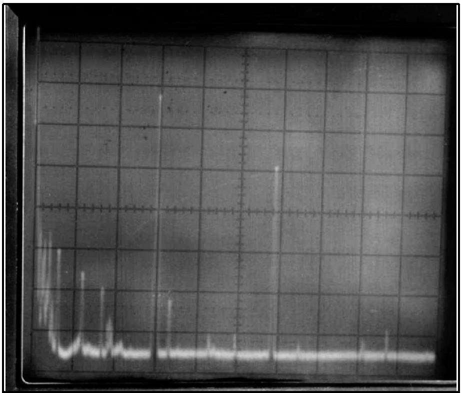


Fig 8: Performance of filter, scond harmonic at 26dBc.

5

Summary

In practice, an SSB amplifier of this type should be driven to full output up to a maximum 1dB compression point. This approximately corresponds to a value of 25% of the maximum possible output. In our example, the manufacturer gives a maximum output level of 37W for clean cut modulation. In linear mode (e.g. for SSB), however, the amplifier is suitable for only approximately 10W.

6

Literature references

[1] Wolfgang Schneider. DJ8ES Hybrid PA for 2m using M57727 VHF Communications 1/94 pp. 56 - 61

[2] Wolfgang Schneider. DJ8ES 2-tone generator for 145MHz VHF Communications 4/02 pp. 216 - 227

Henning-Christof Weddig, DK5LV

A modern 50/28MHz converter part 2

Continuation from VHF Communications, 2/2004

The circuit diagram on page 109 of issue 2/2004 did not reproduce very well, a copy can be downloaded from the VHF Communications web site – Ed.

Following the general consideration and circuit descriptions, we now go on to assembly, putting into operation and measurements using the high-level signal tolerant converter for 50MHz.

5. Construction

The LNA printed circuit board layouts can be seen in Figs. 30 and 31. The corresponding component layouts for wired and SMD components are shown in Figs. 32 and 33, and the fully loaded top and bottom sides of the prototype board can be seen in Figs. 34 and 35.

The layouts for the converter circuit board are shown in Figs. 36 and 37 and the component layouts are shown in Figs. 38 and 39. Figs. 40 and 41 show the fully loaded top and bottom sides of the converter board.

If DIY circuit boards are used, the earth surfaces of both boards must be through hole plated at several points, and in particular beneath the amplifier IC and the mixer.

The supply voltage should be set to 8V on the voltage regulator before the RF 2360 amplifier is soldered in.

The fastest way to align the filter is using a sweep frequency test rig. For optimal alignment of the diplexer, the frequency response and the matching should be observed simultaneously.

6. Measurements on complete apparatus

6.1.0 LNA Noise factor

The noise factor of the amplifier should be approximately 2dB [9]. This value could not be verified since no noise factor meter was available.

6.1.1 Determination of the 1dB compression point

As per data sheet, the 1dB compression point should lie at 10MHz for typical outputs of 22.5dBm and 500MHz for typical outputs of 25.1dBm. The operat-

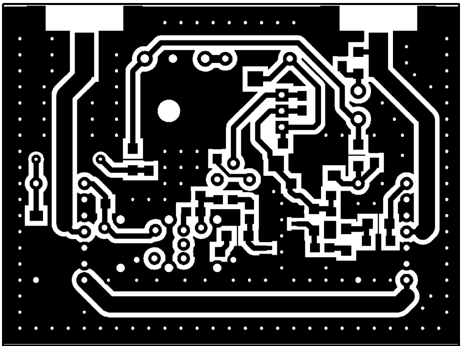


Fig 30: Bottom side of PCB layout for LNA.

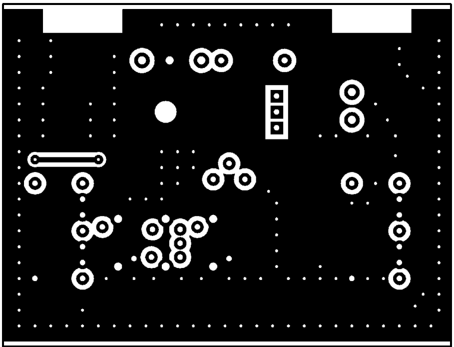


Fig 31: Top side of PCB layout for LNA.

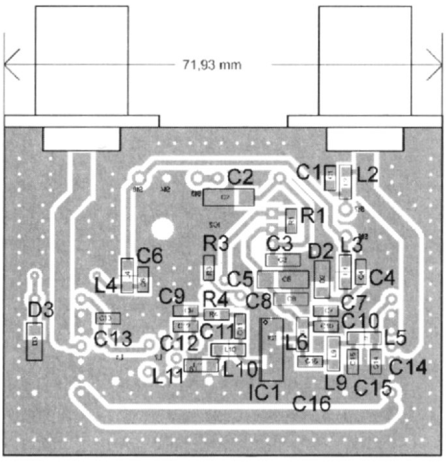


Fig 32: SMD component layout for LNA.

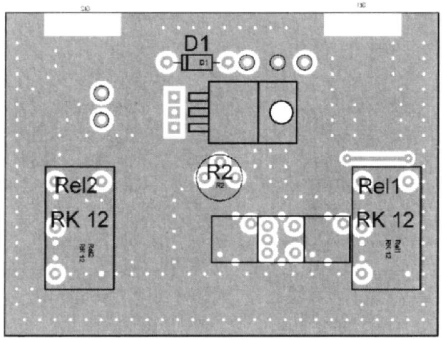


Fig 33: Component layout for LNA.

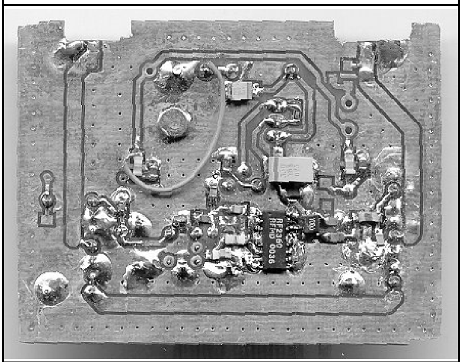


Fig 34: Picture of SMD components mounted on LNA PCB.

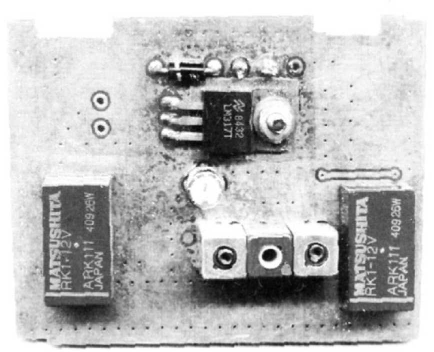


Fig 35: Picture of components mounted on LNA PCB.

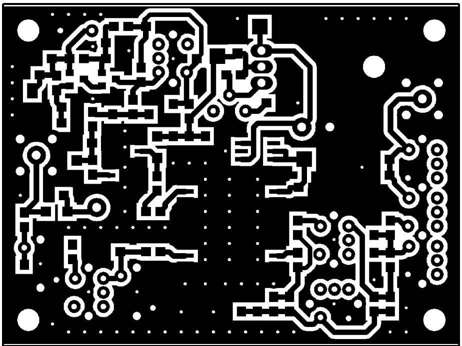


Fig 36: Bottom side PCB layout for converter.

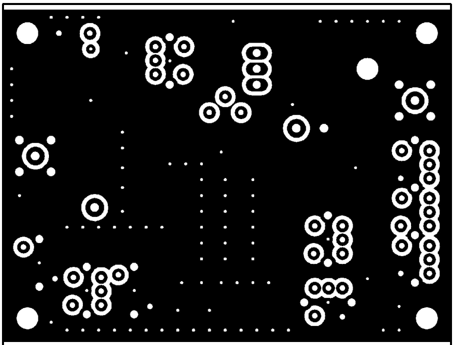


Fig 37: Top side PCB layout for converter.

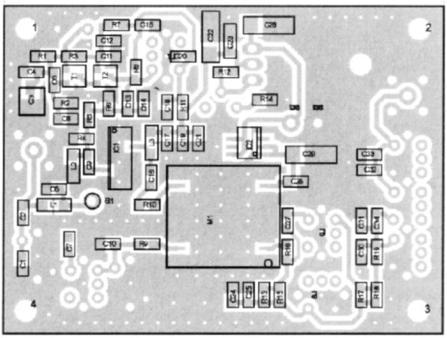


Fig 38: SMD component layout for converter.

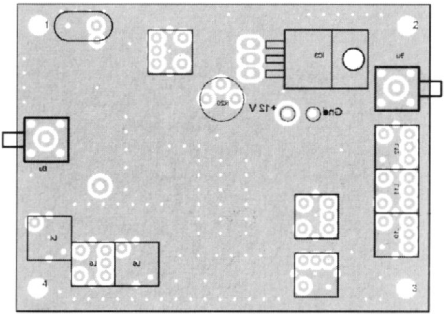


Fig 39: Component layout for converter.

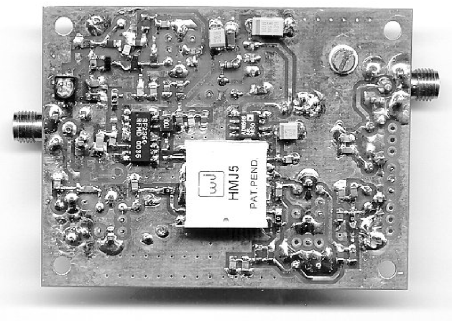


Fig 40: Picture of SMD components mounted on converter PCB.

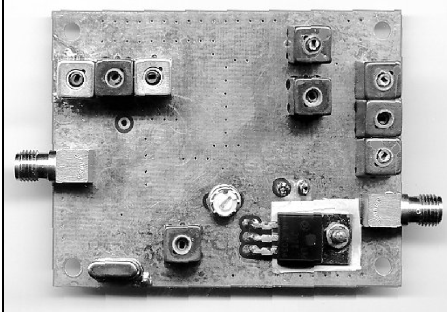
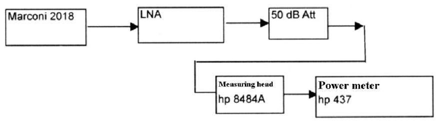


Fig 41: Picture of components mounted on converter PCB.

Table 7: Testing the 1dB compression point of the LNA.



P_{in} dBm	P_{out} dBm	$P_{out\ ideal}$ dBm
-20	-0,89	-0,89
-19	0,12	0,11
-18	1,12	1,11
-17	2,08	2,11
-16	3,07	3,11
-15	4,02	4,11
-14	4,97	5,11
-13	6,34	6,11
-12	7,29	7,11
-11	8,26	8,11
-10	9,2	9,11
-9	10,15	10,11
-8	11,13	11,11
-7	12,09	12,11
-6	13,05	13,11
-5	14,01	14,11
-4	14,96	15,11
-3	16,14	16,11
-2	17,09	17,11
-1	18,04	18,11
0	18,95	19,11
1	19,86	20,11
2	20,79	21,11
3	21,69	22,11
4	22,55	23,11
5	23,37	24,11
6	24,13	25,11
7	24,76	26,11

ing conditions specified are +7V power supply and 25 °C ambient temperature. A power supply of + 8V was selected for the prototype.

Table 7 shows the measurement technique and the measurement table for the associated output for inputs with a single-tone level of -20dBm up to +7dBm. Fig. 42 shows the corresponding diagram

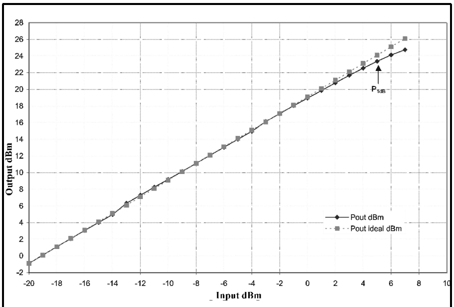


Fig 42: Graph showing 1dB compression point for LNA.

based on these readings.

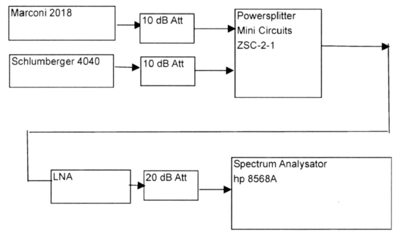
The dotted line represents the straight line for the idealised output. For a divergence of 1dB between the idealised and real curves, the 1dB compression point is obtained; here it lies at an output of +24dBm.

6.1.2 Determination of intercept point

Table 8 shows the measurement technique and the measurement table for the associated output for inputs with a two-tone level of twice -15dBm to +0dBm. Additional 10dB attenuators increase the necessary decoupling between the test transmitter output and input of the hybrid power adder for measuring the two test transmitter outputs against one another, in order not to generate any inherent intermodulation.

Fig. 43 shows the diagram based on these readings. The two dotted lines represent the straight line of the idealised output or intermodulation products. The two straight lines come into contact at the intercept point, which, when projected onto the x axis gives the input intercept point, and when projected onto the y axis gives the output intercept point. As specified in the data sheet, the $OPIP_3$ amounts to +36dBm.

It is also interesting to observe that the intermodulation products increase some-



P_{in}/Ton	P_{out}/Ton	PEP	IMD	d_3	$IPIP_3$	$OPIP_3$
dBm	dBm	dBm	dBm	dB	dBm	dBm
-15	3,7	9,7	-61	64,7	17,35	36,05
-12	6,7	12,7	-52	58,7	17,35	36,05
-9	9,6	15,6	-44	53,6	17,8	36,4
-6	12,3	18,3	-34	46,3	17,15	35,45
-3	15,6	21,6	-23	38,6	16,3	34,9
0	17,6	23,6	-12	29,6	14,8	32,4

Table 8: Intermodulation measurements of LNA.

what more sharply than is suggested by the "theory".

6.2 Converter

Unfortunately, the noise factor of the converter could not be determined directly either.

6.2.0 Determination of 1dB Compression point

Table 9 shows the measurement technique and the measurement table for the associated output for inputs with a single-tone level from 0dBm to +2 dBm. Fig. 44 shows the diagram based on these readings. The dotted line represents the straight line of the idealised output.

The result of this measurement is amazing, since no divergence from the measured output can be detected. However, since the RF output meter measures the broadband output, harmonics can also be measured. On the other hand, the band filter at the output filters out any harmonics.

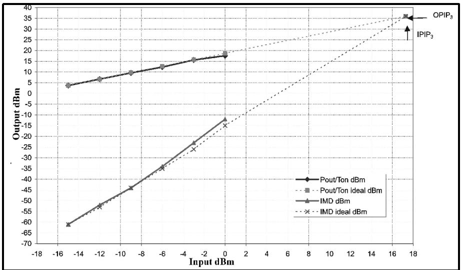


Fig 43: Graph showing results of intermodulation test on LNA.

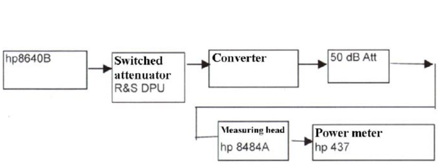
6.2.1 Determination of intercept point

Table 10 shows the measurement table for the output for a two-tone level of twice – 6dBm to 0dBm. Fig. 45 shows the diagram based on these readings. Owing to the restricted dynamic range of the spectrum analyser and the restricted output of the two-tone generators used, only three readings could be taken.

The two dotted lines represent the straight line of the idealised output or intermodulation products. The two straight lines meet at the intercept point, which gives the input intercept when projected onto the x axis and the output intercept point when projected onto the y axis. As opposed to the data sheet specifications, the $IPIP_3$ amounts to "only" +30dBm, instead of +38dBm.

Another interesting comment is the observation that the intermodulation products increase somewhat more weakly than would be expected from the "theory".

Table 9: Testing the 1dB compression point of the converter.



P_{in} dBm	P_{out} dBm	$P_{out\ ideal}$ dBm	Amplification dB
0	-7,78	-7,8	-7,78
1	-6,61	-6,8	-7,61
2	-5,56	-5,8	-7,56
3	-4,62	-4,8	-7,62
4	-3,65	-3,8	-7,65
5	-2,78	-2,8	-7,78
6	-1,42	-1,8	-7,42
7	-0,4	-0,8	-7,4
8	0,57	0,2	-7,43
9	1,58	1,2	-7,42
10	2,58	2,2	-7,42
11	3,53	3,2	-7,47
12	4,51	4,2	-7,49
13	5,52	5,2	-7,48
14	6,57	6,2	-7,43
15	7,52	7,2	-7,48
16	8,48	8,2	-7,52
17	9,44	9,2	-7,56
18	10,4	10,2	-7,6
19	11,38	11,2	-7,62
20	12,34	12,2	-7,66

6.3. Interconnection of LNA and converter

The two assemblies, the LNA and the converter, are now interconnected and the output of the converter is connected to the antenna input of a standard short-wave receiver.

The operational sensitivity of the receiver (20dB SINAD) in the SSB mode at a band width of 2.4kHz has been determined as -110dBm, thus giving the receiver a noise factor of F = 10dB.

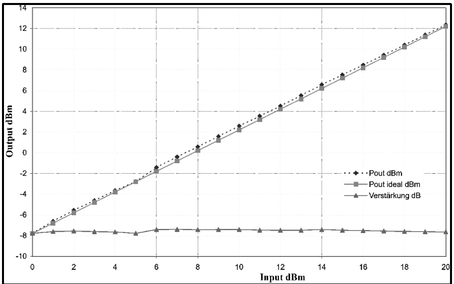


Fig 44 Graph showing the results of the 1dB compression test on converter.

If the converter alone is connected in series, the sensitivity of the system falls to –100dBm. This reduction can be explained by the fact that the converter weakens the input signal by 8dB.

In Fig. 46, the system simulation for the entire system is given, with the sensitivity of the end receiver corrected, as against Fig. 6. The simulation and the reading display a difference of only 0.3dB. This result can be used to confirm that the noise factor for the LNA and the mixer in the converter assumed in the simulation is a good approximation.

If a preamplifier is interpolated, the operational sensitivity rises to -116dBm.

If a 3dB attenuator is connected between the LNA and the converter or between the converter and the end receiver, the sensitivity is reduced to -113.8dBm. This result can also be confirmed using the system simulation.

6.3.0 Determination of intercept point

Table 11 shows the measurement table for the output per tone for inputs for two-tone level with twice -6dBm to 0dBm. Fig. 47 shows the diagram based on these readings. The $IPIP_3$ amounts to +13dBm.

P_{in}/Ton dBm	P_{out}/Ton dBm	IMD dBm	d_3 dB	$IPIP_3$ dBm	$OPIP_3$ dBm
-6	-14,4	-85	70,6	29,3	20,9
-3	-11,4	-75	63,6	28,8	20,4
0	-8,3	-70	61,7	30,85	22,55

Table 10: Measurement results for two-tone test.

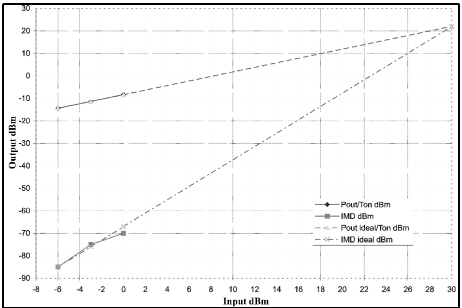


Fig 45: Graph showing results of intermodulation test on converter.

The relevant measurement curves are represented in Figs. 48 and 49.

It is also interesting to observe that the curve of the intermodulation products tends to conform to the dotted curve of the theoretical value. It seems as if the rather sharper increase for the intermodulation products of the LNA is compensated for by the weaker rise for the converter.

It is striking that the intercept point for the converter when interconnected with the LNA is somewhat improved (see Fig. 46, $OPIP_3$ of mixer +31dBm). However, the measurement was carried out using the output matching of the RF 2360 in the LNA, which has not yet been optimised.

6.3.1 Converter's spurious

Finally, the converter's spurious was measured at the intermediate frequency output. For this purpose, a signal with a frequency of 50MHz and a level of 0dBm is fed in at its RF input (see Fig. 50). Table 12 shows the individual spurious levels. The highest level belongs to the 22MHz oscillator signal, with a level of approximately -40dBm, and according to Fig. 50 the first oscillator harmonic (44MHz) lies at approximately -54dBm. All other levels are mixed products of the oscillator signal and the input signal and are thus dependent on the level.

If a signal is fed into the intermediate frequency output with a frequency of 28MHz and a level of 0dBm, then at the RF input, in addition to the desirable 50MHz signal, we obtain other spurious outputs, the frequencies and levels of these are listed in Table 13.

This table can be used to estimate the filter requirement that is needed for the operation of the converter as a transverter. The first harmonic of the quartz oscillator interferes with this operation. Owing to the small frequency interval to the 50MHz useful signal, it is not a simple matter to achieve suppression.

7. Outlook

It is unfortunate that the HMJ-5 is suitable only for frequencies >40MHz. It would make a good and evenly matched alternative to the expensive "Super High Level" Schottky diode ring mixers in a short-wave receiver!

P_{in}/Ton	P_{out}/Ton	IMD	d_3	$IPIP_3$	$OPIP_3$
dBm	dBm	dBm	dB	dBm	dBm
-24	-13	-90	77	14,5	25,5
-21	-10	-80	70	14	25
-18	-7	-70	63	13,5	24,5
-15	-4	-61	57	13,5	24,5
-12	-1,4	-52	50,6	13,3	23,9
-9	1,7	-44	45,7	13,85	24,55
-6	4,5	-34	38,5	13,25	23,75
-3	7,2	-23	30,2	12,1	22,3
0	10,1	-15,2	25,3	12,65	22,75

Table 11: Measurement results of two-tone test.

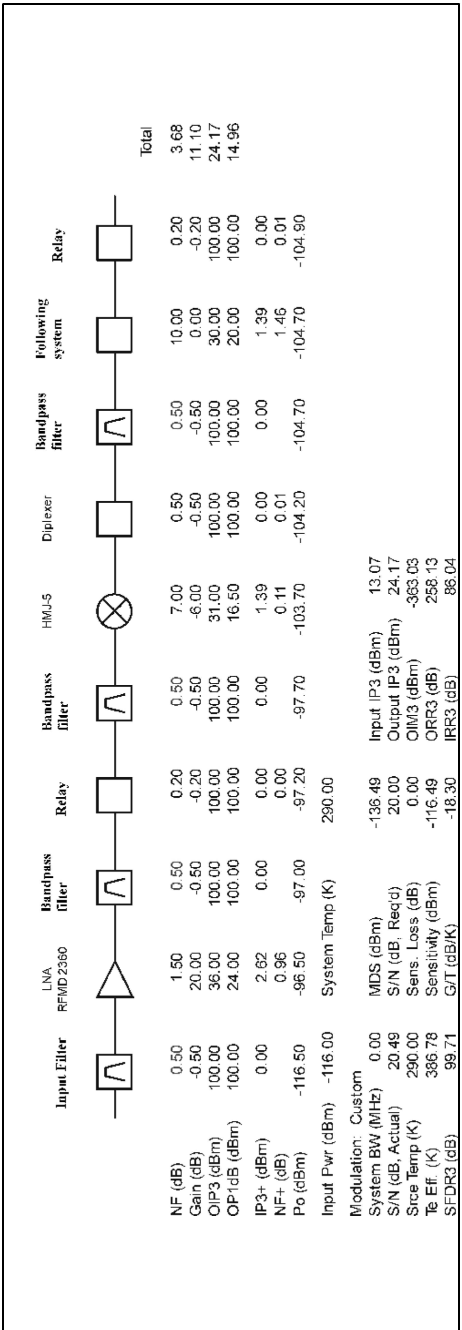


Fig 46: System simulation of the entire system.

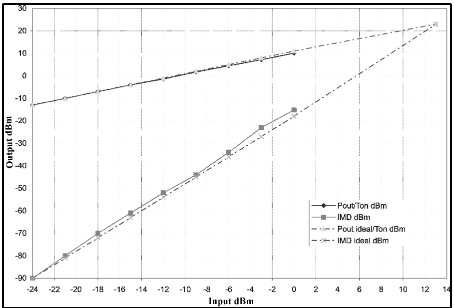


Fig 47: Graph showing results of intermodulation test on converter and LNA.

8. Literature

[1] Considerations on the design of high-level signal resistant receiver front ends for the 6-m, 2-m., 70-cm. and 23-cm. band with modern components; Dipl. Ing. Henning Christof Weddig; Proceedings of 46th VHF Congress, Weinheim 2001

[2] Considerations on the design of high-level signal resistant receiver front ends for the 2-m. and 70-cm. band with modern components; Dipl. Ing. Henning Christof Weddig; Proceedings of 47th VHF Congress, Weinheim 2002

[3] 28/50 MHz transverter; Wolfgang Schneider DJ8ES; VHF Communications 2/1995, Pages 107 - 111

[4] 50 MHz transverter for short-wave transceiver; Martin Steyer, DK7ZB; Funkamateur 8, 9, 10 /1995

[5] Data sheet HMJ-5; Watkin Johnson; www.wj.com

[6] Data sheet RFMD 2360; RF Microdevices; www.rfmd.com

[7] Reducing IMD in High-Level-Mix-

Frequency (MHz)	Level (dBm)	Mix product
16	-65	3*LO – RF
22	-40	LO
28	-7,26	Gewünschte ZF
38	-60	4*LO-RF
44	-54	2*LO
50	-66	RF (Eingangssignal)
56	<-80	2*RF-2*LO
60	<-80	5*LO-RF
72	-66	RF+LO
84	<-80	3*RF-3*LO

Table 12: Table showing individual spurious levels.

ers; John B. Stephenson KD8 OZH; QEX May/June 2001

[8] Personal contact with Roy Allan, Fa. Watkin Johnson; electronica 2002

[9] High-level signal resistant LNA for the 2-m. band; Henning Weddig; DUBUS 4/2002

[10] Diplexer for ring mixer; Eugen Berberich DL8ZX; VHF Communications 1/1998 pages 11 - 17

[11] Matching circuits for diode ring mixers; Joachim Kestler DK1OF; VHF Communications 1/1976 pages 13 - 18

[12] Modern input section for 2-m. receivers with wide dynamic range and low intermodulation distortion levels; Michael Martin DJ 7VY; VHF Communications 4/1978 pages 218 - 229

[13] www.qrp-props.net

[14] MIMP, Motorolas Impedance Matching Program; Dipl. Ing. Henning Christof Weddig; VHF Communications 3/2001, Pages 130 - 138

[15] Data sheet RF 2360; Fa. RF Microdevices; www.rfmd.com

[16] The Diplexer Filter; ARRL Handbook 2002; Pages 16-39 to 16-40, see also: W.E. Sabin, W0IYH; Diplexer Filters for the HF MOSFET Power Amplifier; QEX July/August 1999

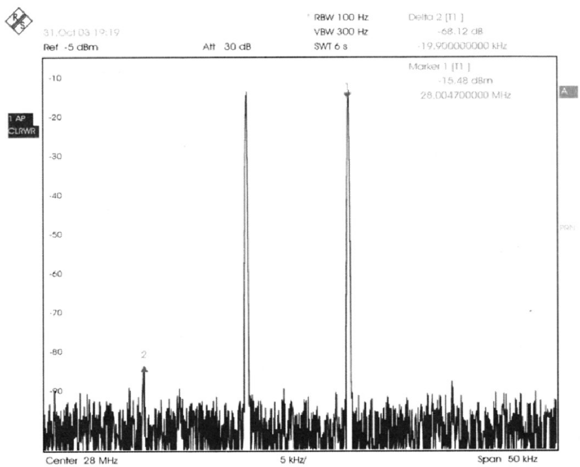


Fig 48: Intermodulation measurement on the converter. F=50.00MHz and 50.01MHz at -6dBm.

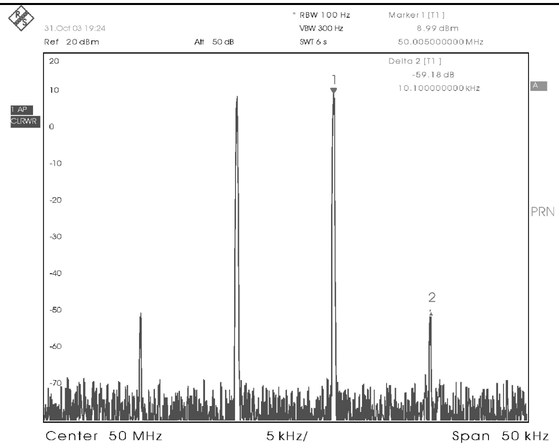


Fig 49: Intermodulation test results on the converter. F=50.00MHz and 50.01MHz 0dBm.

9. Appendix

Parts list for 50MHz converter

Bu1	SMA angle piece	
Bu2	SMA angle piece	
C1,10	150pF	SMD 0805
C2	1nF	SMD 0805
C3	2 – 6pF	TZB-4A
C4	5.6pF	SMD 0805
C5	10nF	SMD 0805
C6	47pF	SMD 0805
C7	18pF	SMD 0805
C8,17	100pF	SMD 0805
C9	120pF	SMD 0805
C11,12	10pF	SMD 0805
C13	47pF	SMD 0805
C14	470pF	SMD 0805
C15,16	10nF	SMD 0805
C18,28	10nF	SMD 0805
C19	1nF	SMD 0805
C20,21	10nF	SMD 0805
C22,26	10µF / 25V	SMD
C23	100nF	SMD 1206
C24,25	150pF	SMD 0805
C27	33pF	SMD 0805
C29	10µF / 25V	SMD
C30	220pF	SMD 0805
C31,32	82pF	SMD 0805
C33	220pF	SMD 0805
C34	22pF	SMD 0805
IC1	RF 2360	SO16
IC2	ADM 666A	SO8
IC3	LM 317 T	TO220
L1	270nH	SMD 1206
L2	560nH	SMD 1206
L3	10µH	SMD 1206
L4	56nH	511830
L5	0,795µH	5048
L6	56nH	511830

Frequency (MHz)	Measurement (dBm)	Mix product
16	-81	2*LO – RF
22	-65	LO
28	-59	RF
38	-36	3*LO-RF
44	-51	2*LO
50	-8	Gewünschte „ZF“
54	-74	5*LO-2*RF
60	-36	4*LO-RF
62	-50	3*RF-LO
72	-43	2*LO + 2* RF
82	-57	5*LO-*RF
ar88	-78	4*LO

Table 13 Spurious frequencies measured with a 0dBm 28MHz input signal.

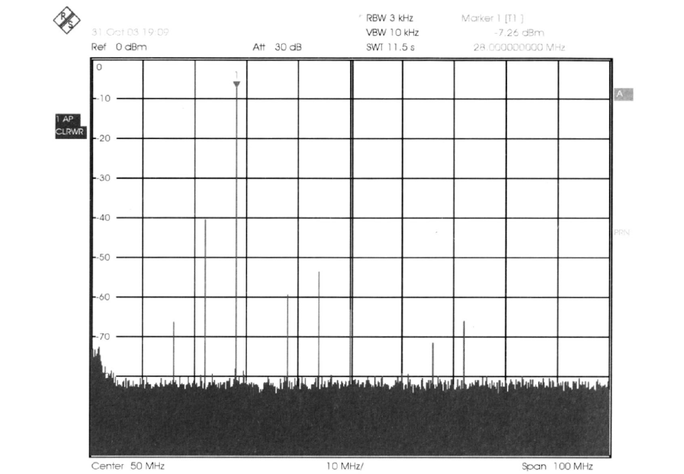


Fig 50: Spurious test results on the converter.

L7	1µH	max 5048	C4,6	10nF	SMD 0805
L8	105nH	5061	C7,9	100pF	SMD 0805
L9	1µH	5048	C8	100nF	SMD 1206
L10,12	105nH	5061	D1	1 N 4001	
L11	1,5µH	525200	D2,3	LL 4148	
M1	HMJ-5	SMD	IC1	RF 2360	SO16
Q1	22MHz	HC-18U	IC2	LM 317 T	
R1	1k8	SMD 0805	L1	56nH	511830
R2	220	SMD 0805	L10	180nH	SMD 1206
R3	3k3	SMD 0805	L11	22nH	SMD 1206
R4,6	270	SMD 0805	L2	270nH	SMD 1206
R5	15	SMD 0805	L3,4	1µH	SMD 1206
R7,8	3k3	SMD 0805	L5	50nH	SMD 1206
R9,10	0R	SMD 0805	L6	10µH	SMD 1206
R11,13	100	SMD 0805	L7	0.795µH	5048
R12	240	SMD 0805	L8	56nH	511830
R14	1k	SMD 0805	L9	56nH	SMD 1206
R15	100	SMD 0805	R1	240R	75R
R16,19	0R	SMD 0805	R2,2	1k	SMD 0805
R17,18	100	SMD 0805	R4	0R	SMD 0805
R20	1k	75 R	Rel1,2	RK 12	
St1-3	1.3mm	Soldering rod	St1,2	N-Flange	
T1,2	BFS 19	SOT 23	St3-8	1.3mm	Terminal pin

Parts list for 50MHz converter:

C1,16	10nF	SMD 0805
C10	1000pF	SMD 0805
C11	47pF	SMD 0805
C12	12pF	SMD 0805
C13	150pF	SMD 0805
C14,15	56pF	SMD 0805
C25	33µF /16V	SMD Tantalum
C3	100nF	SMD 1206

Franco Rota, I2FHW

Franco's Finest Microwave Absorbers

Franco Rota runs an RF component supply company in Italy called R F Elettronica. His main objective is to sell bulk components such as SMD parts to the electronics industry. He attends some radio rallies in Europe and often has interesting items for sale that can be used or adapted by radio amateurs for use on the amateur bands. This is the second article of a regular series that will describe one of Franco's products with details of its use by radio amateurs. If you require more details about the products you can contact VHF Communications or Franco – info@rfmicrowave.it

1.0

Introduction – extract from R F Elettronica catalogue

Microwave absorbers, usually for RF applications, can be divided in two categories:

- For anechoic chambers, for antennas or free space, they usually work through a gradual impedance change and they are available in pyramidal shape for anechoic chambers. They are often used to attenuate the unwanted side lobes into the radar antennas, in this case they are multilayer with a thickness over 1cm.
- For cavities (metal boxes), every box behaves like a cavity excited by several secondary propagation modes, for higher frequencies or in medium size boxes the RF circuit will also have many self-oscillations at various frequencies. Since every box is different in size shape and operating frequency the calculation of secondary propagation modes is very difficult.

The absorber placed in the cavity will act to dampen the resonance in several different ways by changing the characteristic of the cavity. The microwave absorber will also lower the Q of the cavity. For best operation the absorber must be placed near a metallic surface (cover of the box). As a general rule, lower frequency cavity resonances would require a heavier loaded and thicker material for equivalent absorption, cost considerations point you towards a lighter thinner material. An additional desirable feature is their low conductivity so they will not short out circuits if they accidentally come into contact. MAS... and MAF-3A absorbers (see table 1) are used only in cavities (metal boxes) on a metal surface, they have an auto adhesive film to simplify the installation. MAF-1 0 and MAF-1 9, thanks to a big thickness, are

Table 1: Microwave Absorbers from R F Elettronica catalogue.

	Microwave Silicone absorber		Microwave foam absorber		
			LS26	AN73	AN74
Thickness	0.8mm (0.030")	2.6mm (0.100")	3.1mm (1/8")	10mm multiplayer	19mm multilayer
Electrical conductivity	~MΩ		~KΩ	~MΩ	~KΩ Black side ~MΩ White side
Temperature range	-50°C / +190°C		-50°C / +120°C	-50°C / +130°C	-50°C / +90°C
Assembly	By acrylic transfer film adhesive		By acrylic transfer film adhesive	By acrylic transfer film adhesive	---
Reflection loss	>6dB >6GHz	>6dB >1.8GHz >10dB 2 – 4GHz	>6dB >8GHz	>10dB >5GHz ~18dB >7GHz	>10dB >2GHz >20dB >4GHz
Type	Flexible, carbonyl iron loaded silicone rubber		Flexible low density carbon impregnated foam		
Application	For cavity >4GHz	For cavity >1.5GHz	For cavity >5GHz	Both cavity and free space >3.5GHz	Both cavity and free space >1.5GHz
Cod.	**MAS-0.8A-5x10** 5 x 10cm **9.00€**	**MAS-2.6A-5x10** 5 x 10cm **15.00€**	**MAF-3A-10x20** 10 x 20cm **7.50€**	**MAF-10A-10x20** 10 x 20cm **12.00€**	**MAF-19-10x20** 10 x 20cm **8.00€**
Cod.	**MAS-0.8A-10x10** 10 x 10cm **17.00€**	**MAS-2.6A-10x10** 10 x 10cm **29.00€**	**MAF-3A-20x20** 20 x 20cm **14.00€**	**MAF-10A-20x20** 20 x 20cm **22.00€**	**MAF-19-20x20** 20 x 20cm **14.50€**
Cod.	**MAS-0.8A-15x30** 15 x 30.4cm **54.00€**	**MAS-2.6A-15x30** 15 x 30.4cm **92.00€**	**MAF-3A-30x60** 30 x 60.9cm **49.00€**	**MAF-10A-30x60** 30 x 60.9cm **75.00€**	**MAF-19-30x60** 30 x 60.9cm **50.00€**
Cod. Max size	**MAS-0.8A-30x30** 30.4 x 30.4cm **104.00€**	**MAS-2.6A-30x30** 30.4 x 30.4cm **176.00€**	**MAF-3A-60x60** 60.9 x 60.9cm **95.00€**	**MAF-10A-60x60** 60.9 x 60.9cm **140.00€**	**MAF-19-60x60** 60.9 x 60.9cm **94.00€**

also suitable for free space absorbing, for example to reduce lobes on antennas moreover these last two types give high attenuation if used in a cavity.

2.0 Laboratory tests

To examine the properties of the absorber material in my catalogue I carried out some tests in my laboratory.

- Step 1. I built a 50Ω line with the worlds best performance laminate (i.e. Rogers duroid RT5870 with εr 2,33 and 60mils thickness = 1.52mm) into a small box 26x36x16mm. This box, as you can see in Fig 1, was suitable only for the higher microwave frequency range. This small box was able to generate secondary propagation modes only at higher frequencies. The box was terminated at both ends with SMA connectors types, female + male, in order to avoid any further error due to the adapter. The p.c. board was soldered to the metal box all over its perimeter in order to ensure the best ground. The box was kept without any cover.
- Step 2. I did a measurement with a network analyser, Agilent 83640B plus 8757D, the result of this measurement is shown in Fig 2 (box without cover) The graph shows only the insertion loss of the p.c. board plus various little mismatches.
- Step 3. Then I put the original cover on the box and tested the new insertion loss, as you can see in Fig 2 there were secondary resonance modes at higher frequencies in the small box i.e. 17.5, 19, 20GHz etc. and a heavy insertion loss.

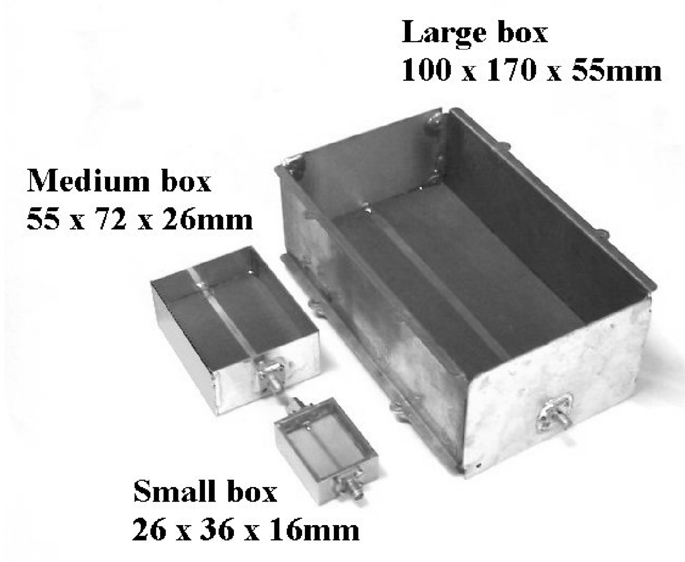


Fig 1: Picture of the three boxes used for the laboratory tests.

- Step 4. Then I fixed two different microwave absorbers on the internal side of the cover, as you can see in Fig 2 this is equal to the original condition (without cover), so it means that the condition with the cover plus absorber is equal to the condition without cover, in other words the 50Ω internal line "does not see" the cover.
- Step 5. Then I built a 50Ω line with the same laminate but into two bigger boxes, the purpose of building bigger boxes is to shift secondary modes at lower frequencies (see waveguide principle).
- Step 6. For the bigger box I had to change the microwave absorber because the absorber for higher frequencies was not able to work at lower frequencies (see specifications from catalogue). The results are shown in Fig 3 and Fig 4.

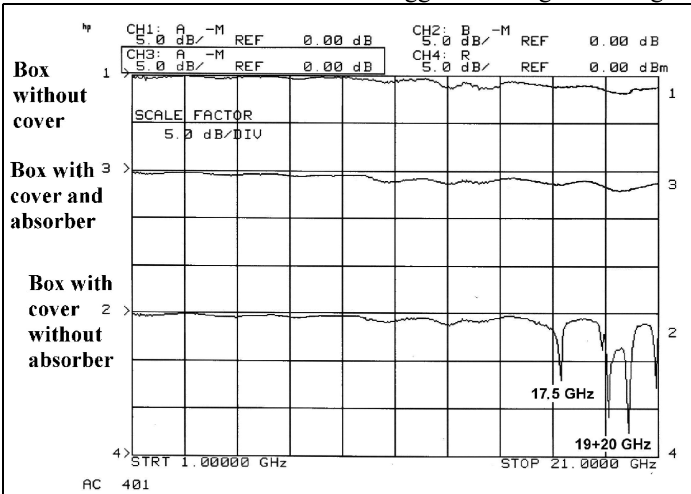


Fig 2: Test results for the small box.

Microwave absorber types:

MAS-0.8A + MAF-3A

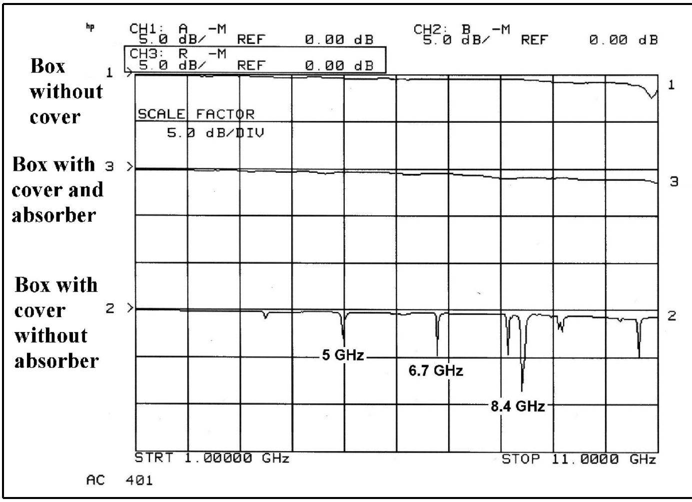


Fig 3: Test results for the medium box.

Microwave absorber types:

MAS-0.8A + MAF-3A

3.0 References

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[5] R F Elettronica web site http://www.rfmicrowave.it

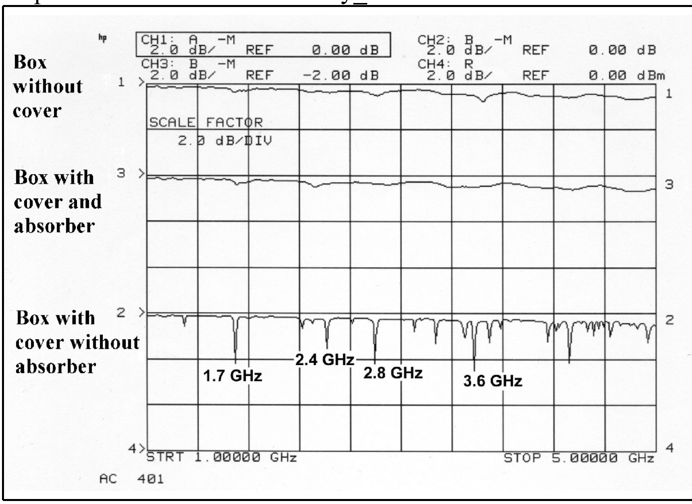

Fig 4: Test results for the large box.

Microwave absorber types:

MAF-19 + MAS-2.6A

Gunthard Kraus, DG8GB

Internet Treasure Trove

Vivaldi antennas

We know that antenna developers come up with numerous “infinitely variable concepts”, which they never stop playing around with and changing – there’s no end to it. This often leads to solutions that we would never have dreamed of. The “Vivaldi antenna” falls into this category. Just take a look at how something like this makes out in a radio telescope. And if this is your kind of thing, a search engine can provide plenty of additional links on the subject.

Address:
http://brown.nord.nw,ru/vkh/vfv.1.htm

MDBC

It’s a safe bet that no one will guess what this abbreviation means, since for once, and for a change, we’re dealing with an interesting and meaningful application of high-frequency technology in medicine. So we won’t keep you in suspense any longer. The University of Victoria in Canada is introducing the concept of a “microwave detector for breast cancer”. Since this page summarises data ranging from principles through simulation to balun and microstrip design, the high-frequency specialist will also find it worth reading.

Address:
http://www.exe.uvic.ca/499/2002b/group11/mdbc.html

Electromagnetic radiation

This is a concept that is on everyone’s lips nowadays, and is even causing many people to have panic attacks. So this homepage is extremely useful, as you can look forward to investigating the physical and technical principles, the measuring process and the range of measuring devices on offer - and there’s even a downloadable test report from the Technical Inspections Association.

Address: http://www.elektrosmog.de/

Antenna Software

This page offers a total of 115 links for you to click on, and each one leads to a program or a set of programs for antenna calculation. The same homepage also offers any amount of practical examples, and they're even broken down by type or frequency range.

Address:
http://members.fortunecity.com/xe1bef/software=antennas.htm

Antenna Tutorials

Would you like a bit more information about the principles of antennas? If so, please just take a look at this page, as information is presented here in an attractive form, and it's a joy to read. There are also additional links to half the antenna world.

Address: http://www.electronics-tutorials.com/antennas/antenna-basics.htm

Spread Spectrum

Anyone who wants to become better informed by using an easy to understand introduction to this area should pay a visit to this address. Well put together, easy to understand, not too wide-ranging and yet precise – this is the right mix for a pleasant introduction.

Address:
http://www.keytelemetering.com/ABC_of_spread.htm

Since even more interesting things are on offer, we're also giving you the link to the main page for tutorials ("College Page").

Address:
http://ww.keytelemetering.com/College.htm

However, if you find the Spread Spectrum introduction a bit too brief, just try this link.

Address:
http://cobalt.et.tudelft.nl/~glas/ssc/techn/techniques.html

Semi-conductor manufacturers

This is probably the biggest collection of German language direct links that you can find on the Internet. Everything's already alphabetically sorted, and even every exotic little shop is accessible (provided it has an Internet address). But anyone taking a closer look at this homepage will find still more interesting information.

Address:
http://www.aufzu.de/semihalbleit.html

AnTeg

Would you like a few application notes on the subject of microstrips / antennas / couplers? There's some stuff you can download here, but it's also worth taking the time just to look.

Address:
http://www.anteg.net/html/selected_papers.html

Berkeley Ultra-Wide Band Group

There's a lot happening at most universities, and when the right team is on hand some very interesting things come out of their projects.

For example, just take a look at the project entitled "A Subsampling Radio Architecture for 3-10GHz UWB". Look at the way these microwave freaks present and explain their results: you can do that too (...which is why I think it's great!).

Address:
http://bwrc.eecs.berkeley.edu/Research/UWB/pubs.htm

Wikipedia

This sounds as if it should have something to do with Hawaii and the South Seas, but in reality it's a giant online encyclopedia and user forum in several languages. You can even contribute to it if you wish. It's somewhat hard to describe, but all our Earthly wisdom is categorised and made available, broken down by subject. Just take a look, choosing a subject that interests you.

Address:
http://en.wikipedia.orig/wiki/Main_Page

Radio navigation

The various aspects of radio navigation and the associated processes are the section headings for a PDF dissertation at:

Address:
http://www.navtec.de/personen/acf/dd/dd_inh.htm

Modulation process

You can find a (Powerpoint) presentation on FM and combined modulation signals at the address: http://hta-bi.bfh.ch/E/Laboratories/Telecommunication/cours/modulation/FM_special.ppt

High Frequency Electronics

This page should act as an appetiser. Firstly, it lists the good, informative periodicals that are available for our sector. Secondly, the article headed: "The Design, Fabrication and Measurement of Microstrip Filter and Coupler Circuits" can and should inspire people to a bit of DIY work. Please have a good look round!

Address:
http://www.highfrequencyelectronics.com/Archives/Jul02/HFE0702_Brady.pdf

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A Publication for the Radio Amateur Worldwide

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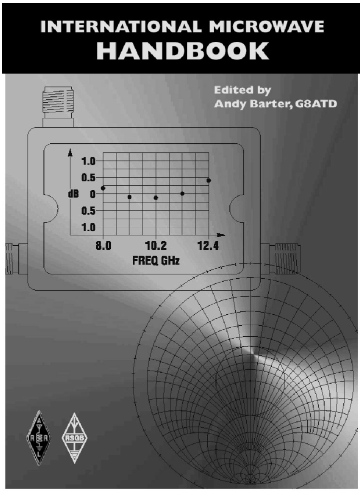


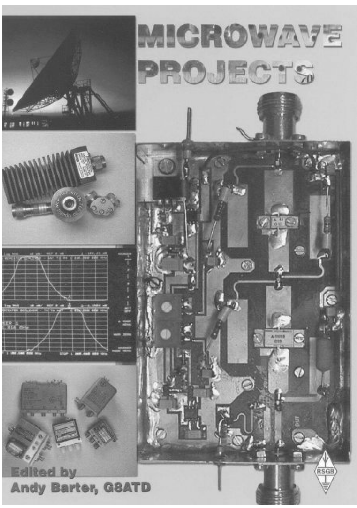
The microwave bands are an excellent area for radio amateurs who want to experiment and construct their own equipment. The RSGB in partnership with the ARRL has produced this invaluable source of reference information for those interested in this area, along with excellent designs from around the world to fire the imagination. Material has been drawn from many sources including the RSGB journal RadCom and the ARRL publications QST & QEX. Alongside this material a truly international range of sources have been used including items from Germany, Denmark, New Zealand, Slovenian and many more.

The earlier chapters of the book provide invaluable reference material required by all interested in this exciting area of experimentation. Techniques and devices are covered in depth, leading the reader to understand better the wide range of equipment and techniques now available to the microwave experimenter. This book contains a wide selection of designs using the latest technology that can reasonably be used by radio amateurs and ranges from ones that can be reproduced by most radio amateurs to those that require a high degree of skill to make.

With the explosion in consumer electronics using microwave frequencies the opportunity to experiment has never been greater and this book is simply the best guide to the area of microwave radio.

Available in the UK for £24.99 from www.rsgb.org/shop and in the USA for $39.95 from www.arrl.org ISBN 1-872309-83-6

Microwave Projects



Microwave Projects is aimed at those who are interested in building equipment for the amateur radio microwave bands.

Packed full of ideas from around the world this book covers the subject with a variety of projects. The book has many contributors who have a wealth of experience in this area and they have produced many projects, design ideas, complete designs and modifications of commercial equipment, for the book.

This title provides much useful information as to what can be achieved effectively and economically. Aimed at both the relative novice and the "old hand" the book also covers useful theory of designing microwave circuit and test equipment for the projects. The book includes chapters covering:

• Signal Sources • Transverters • Power Amplifiers

• Test Equipment • Design

Microwave projects is a must have book for all those who are already active on the microwave bands and those looking for interesting projects to embark on.

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