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Transistor Frequency Multipliers

1.

Introduction

In a previous article we looked at the use of diode multipliers. These all suffer from one serious disadvantage, the conversion loss when multiplying to high orders can be quite high. This makes them only useful for low orders of multiplication of perhaps 3 as a practical maximum.

Using an active device such as a transistor can overcome the inherent loss of the simple diode multiplier, because the transistor can have appreciable gain when used as a multiplier, which eases the design of multiplier chains where high multiplication is required. If the transistor is operated in grounded emitter configuration with the input RF drive applied to the base the impedance is medium and a greater RF voltage swing can be obtained from relatively low drive power.

2.

Principle of Operation

If a transistor is used as an amplifier for a

signal requiring linear amplification then it is limited to the output power it can produce because of the maximum voltage swing on the base or collector. If the input voltage swing exceeds the base-emitter forward voltage the junction starts to behave like a rectifier diode and distortion occurs. We can simplistically think of a multiplier transistor as being two separate items. The first is the diode junction contained within the base-emitter and the second is a very linear voltage amplifier between the base and collector. By overdriving the base-emitter junction we generate harmonics of the input frequency and these are then amplified in a highly linear manner by the collector-emitter portion of the transistor.

Unfortunately it isn't as simple as this, but the simplistic idea forms the basis of all transistor frequency multipliers. We could place a multiplier diode across the base-emitter and couple into the transistor base via a capacitor. By generating harmonics in the external diode these are then amplified by the linear biased transistor. Some commercial two-way radio multiplier chains used this technique. Unfortunately the efficiency this achieves is worse than the diode on its own if we include the DC power being drawn by the transistors before and after the diode multiplier.

By utilising the inherent transistor base-emitter diode junction we have a better

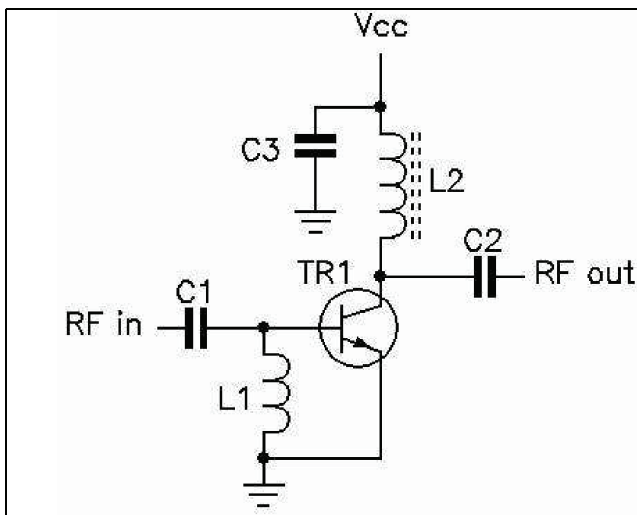


Fig 1: Basic multiplier circuit.

method of generating high levels of harmonic power. Of course we still have to filter out all the unwanted harmonics at the collector and select the desired one with as little loss as possible. However, by altering the conduction angle of the transistor we have a method of enhancing certain harmonics and hence reducing the unwanted ones.

The most basic circuit is shown in Fig 1. Although this will work it does have a number of problems, which we will consider later.

The drive signal to be multiplied is applied to the base of TR1 via C1. The inductor L1 across the base to ground holds the base at DC ground and looks like a high impedance to the input frequency. The emitter is also directly grounded, so for the transistor to conduct the RF voltage across L1 needs to exceed the base-emitter junction voltage of about 0.6V. This means that when the RF voltage is below the threshold nothing happens, but as soon as the base voltage exceeds about +0.6V on the positive peaks of the RF waveform the transistor will start to turn on. If the RF drive is raised even more the transistor will be conducting for a greater portion of the RF envelope and so more collector cur-

rent will flow. The transistor is being operated as a Class C amplifier and the waveform at the collector is similar to a square wave, which is rich in harmonic content. All that is required is a suitable band pass filter to select the wanted harmonic and reject the remainder.

On the face of it this seems to be perfect. But one thing to be aware of is that the multiplier is very critical to the RF drive level, too little and it will snap off and too much and it will saturate and the gain will fall dramatically. Also the threshold is very dependent on the base-emitter forward voltage. If the ambient temperature varies over a wide range the base-emitter voltage does the same. At very low temperatures the voltage required to make the base-emitter junction conduct will be greater than when the ambient temperature is high. So although it works fine in the shack it may not work at all from a contest site on top of a mountain in winter!

The danger with this simple circuit is that the base-emitter junction can be driven very negative on the opposite half cycle and small signal bipolar junction transistors have a limited reverse base-emitter break down voltage, as little as 2V can destroy the junction.

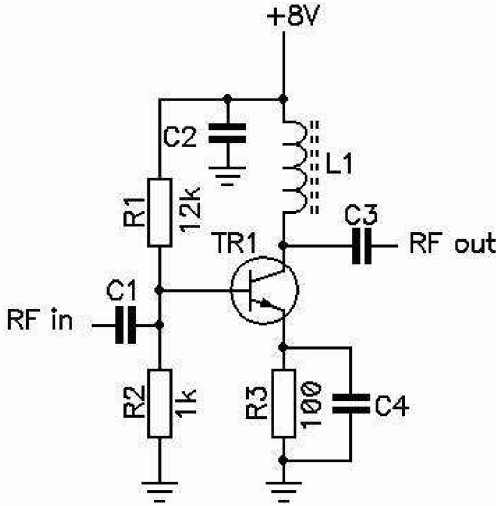


Fig 2: Improved frequency multiplier.

Another failing with this simple circuit is that the impedance presented to the driving stage varies wildly as the drive level varies. Below the threshold voltage the multiplier appears close to an open circuit, at high drive levels the multiplier appears as low impedance, just like the diode multipliers.

3.

Improving the Basic Circuit

The first problem we will address is the temperature sensitivity. In a linear amplifier using the common emitter configuration we normally include a resistor in series with the emitter to ground to provide a small bias voltage. This helps to hold the collector current more stable with variations in temperature.

The second problem is the sensitivity to the RF drive. We can to some extent reduce this tendency by applying a small amount of forward bias to the base-emitter junction with a potential divider of two resistors. By selecting the resistor values such that the base-emitter voltage

is just below the conduction point the RF drive voltage swing is greatly reduced. This translates into less drive power being required and higher input impedance. Fig 2 shows the modifications needed.

The value of the emitter resistor is determined by the order of multiplication required. For high multiplication factors the resistor value is higher than for low order factors. This is to reduce the conduction angle to enhance the higher harmonics. In simple terms we need to move the conduction more towards Class C as the harmonic order increases.

The value of the base potential divider inter-reacts with the emitter resistor. Essentially what we need to achieve is the DC voltage on the base with no RF drive to be just below the conduction point or a very small collector current flowing, a few hundred μA typically. With the values shown in Fig 2 the base voltage with respect to ground is approx. 0.62V. But the collector current flowing in the emitter resistor raises the emitter voltage above ground. For a collector current of 20mA flowing when the base is driven the emitter will be approx. 0.2V above ground, making the effective base-emitter voltage about 0.42V. Hence the input

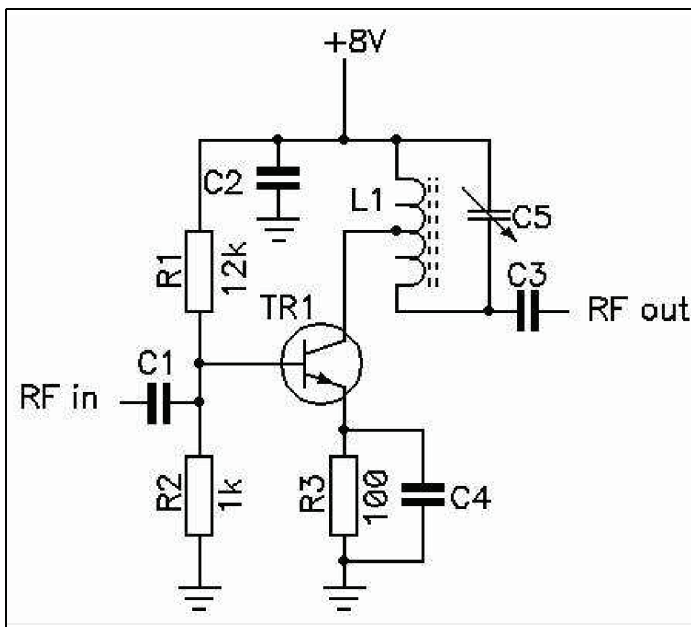


Fig 3: Incorrect collector coupling.

RF drive needs to be greater than about 0.3V peak to turn the transistor on.

The disadvantage of this circuit is the emitter decoupling capacitor; this needs to be a low reactance to not only the input frequency but also all harmonics. This requires quite a low inductance capacitor and a SMD chip type is normally the best choice. If leaded capacitors are used, for example ceramic disks, the emitter decoupling may not be good enough for the higher harmonics and some loss of gain will occur at the higher harmonic products.

4.

Coupling Out Of the Collector the Required Harmonic

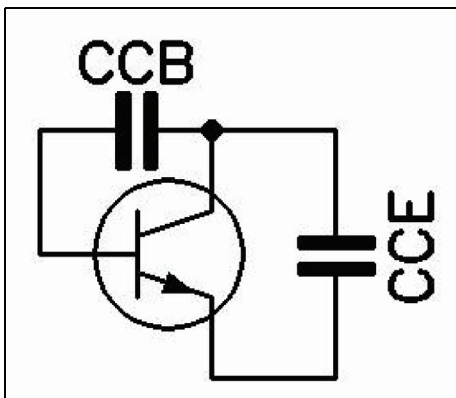
This is where most published designs get it wrong. Although the multiplier stage appears to work satisfactorily often rear-

ranging the circuit a little can make a distinct improvement.

In Fig 1 and 2 the collector is connected to a radio frequency choke with a wide bandwidth. The coupling capacitor serves to block the DC supply and also transfers the AC signal to the following band pass filter. In Fig 3 is shown the wrong way of coupling out the harmonic signal.

The collector of TR1 is tapped down the inductor L1. L1 is resonated to the required frequency by the variable capacitor C5 and this tuned circuit could be the first portion of a multi-pole band pass filter.

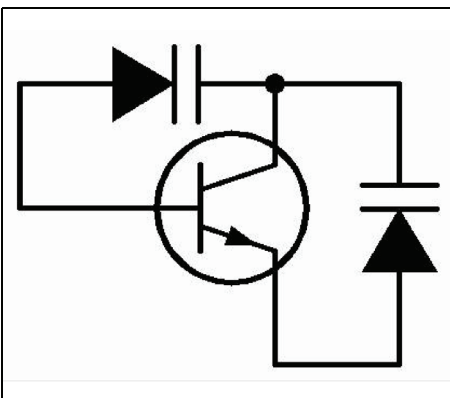
This tapped inductor method is commonly used for amplifiers such as intermediate frequency amplifiers where linearity is critical. The tapping of the inductor allows a good impedance match to the collector, the conjugate match. However, in a frequency multiplier this is exactly the opposite of what we require. To understand this logic we need to look more closely at how the bipolar junction

**Fig 4: Transistor parasitic capacity.**

transistor works and its internal structure.

Fig 4 shows the two major parasitic capacitances inherent in the bipolar junction transistor. These are the collector to base (CCB) and collector to emitter (CCE). There is one other which exists between the base and emitter but this does not affect the operation, only the input matching.

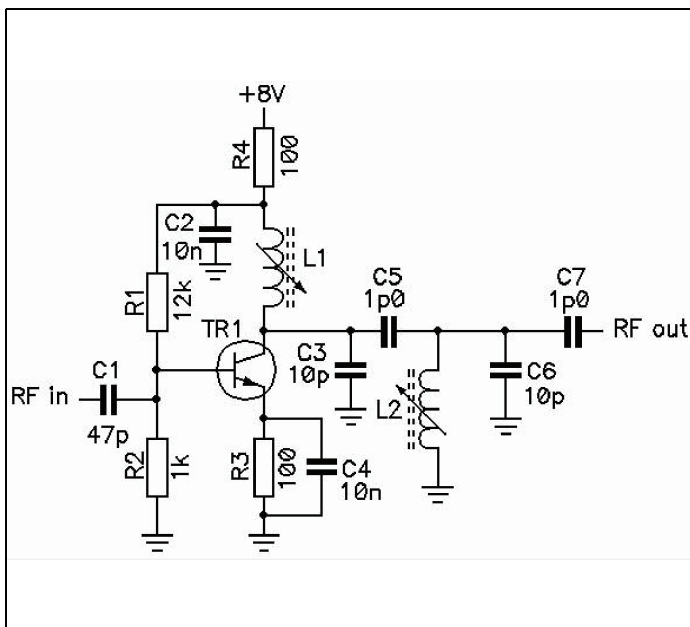
Normally in a small signal linear amplifier application the capacitance is relatively constant and can be tuned out. Because the RF voltages appearing across the junctions are small the capacitances are constant. But in a frequency multiplier with correct collector matching the RF voltages are not small, in fact we want to make them as large as possible, without exceeding the collector-emitter secondary breakdown voltage of the device. The reason is that with a large voltage swing the parasitic capacitance is not constant but behaves like a varactor diode. Motorola in an Engineering Bulletin [1] gave details of how the varactor diode characteristic can be exploited to make more efficient frequency multipliers. This used the MRF629 a 12V/2.5W UHF power transistor as a *parametric multiplier*. This exhibited a power gain of over 6dB when driven by a 100mW signal at 150MHz and developed as much as 700mW output at 450MHz

**Fig 5: Inherent varactor diodes in a BJT.**

when configured as a tripler. The writer used this technique when building the 1152MHz LO chain for a 2C39A power-mixer SSB transverter for 23cm and obtained nearly 1W output at 384MHz. This used 150mW input at 96MHz with the circuit configured as a 4x multiplier. The use of idler circuits at the input and output is the secret to efficient multiplication.

This technique is not just applicable to the MRF629 (which today is obsolete) but even small signal BJT RF transistor exhibit this effect when a sufficiently large RF voltage is developed at the collector. Hence, we need to match the collector to a much higher impedance than suggested by the formula for conjugate matching. This also explains why junction field effect transistors (JFETs) are poor frequency multipliers, as they do not exhibit the same varactor effect as BJTs. Fig 5 shows the inherent varactor diodes in BJT

In Fig 6 is shown an example of the correct collector matching for a frequency multiplier. This uses a two-section top-coupled band pass filter to select the required harmonic. The Q of the tuning components needs to be sufficiently high to develop the required RF voltage swing.



Gig 6: Typical frequency multiplier stage.

The input to the multiplier is via a capacitor with a medium impedance at the operating frequency. The drive source is a low impedance stage such as an emitter follower and with an output voltage swing of at least 1V p-p. The tuned circuit of L1 and C3 selects the required harmonic. This develops the necessary high impedance, and hence the higher voltage swing, at the collector of

TR1. The coupling into the next section of the filter is made via C5, a very low value capacitor to prevent loading of the collector. This capacitor is also the top coupling for the band pass filter so it needs to be a very low value, which suits the circuit configuration well. The second inductor L2 is resonated by C6, the coupling to the next stage is performed by C7 which is also a low value capacitor because we need to prevent loading on the band pass filter, which would alter the selectivity response if excessive loading occurs. The values of the inductors and capacitors need to be chosen to suit the frequency. If more selectivity is required it is often better to incorporate this into the following buffer amplifier before the next multiplier stage.

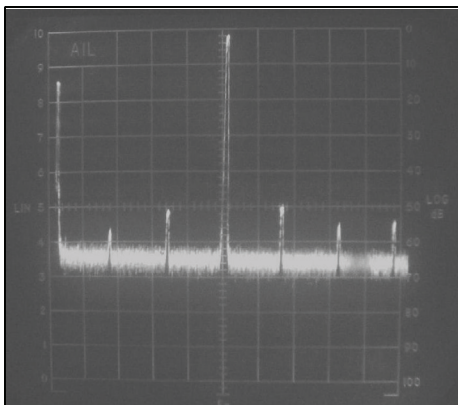


Fig 7: Typical spectrum for a BJT multiplier.

Fig 7 shows the typical spectrum at the output of the band pass filter. This circuit is the one shown in Fig 6 and uses an MPSH-10 transistor as a tripler. The input frequency is 50MHz at a level of 5mW in 50Ω and the wanted output at 150MHz measures approx. +13dBm (20mW). The worst spurious products

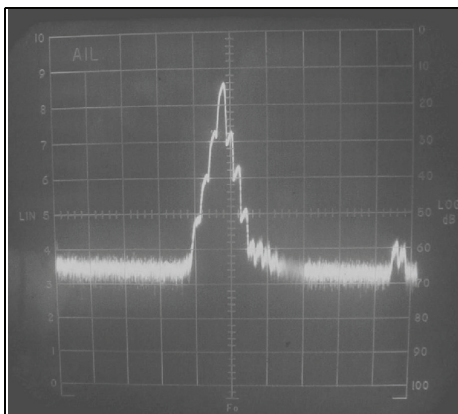


Fig 8: Unstable multiplier spectrum.

are about 50dB down on the 150MHz signal. This will require further filtering in another band pass filter before it is applied to the next multiplier or used by the equipment.

One thing not obvious is why a bipolar junction transistor is the preferred device. Some schematics show junction Fets as multipliers. This is a poor choice because the Fet does not contain the same type of varactor junction as the bipolar. Hence, the drive power required is much greater to get any significant harmonic generation. Fets make good mixers because they are used in a “additive mode” with a second carrier, the local oscillator. The local oscillator energy causes the drain-source current to swing up into the saturation region and the non-linearity is greatest under this condition. The Fet is operated as a saturated switch to “chop” the input waveform and cause additive and subtractive products, one of which is the wanted mixing product. If a junction Fet and a similar die size bipolar junction transistor are compared in a multiplier circuit the bipolar will deliver more harmonic output power and require less drive power. Hence, junction Fets are not very suitable for straight multiplier duty.

5.

Multiplier Stability

In general, frequency multipliers using BJTs are inherently very stable because the input and output are tuned to different frequencies. Unlike a tuned amplifier where the input and output are the same, the only thing that can make a frequency multiplier unstable is either poor layout or the internal parametric components of the transistor. If the drive level is marginal the transistor can exhibit erratic operation. If the input drive varies over too great a range the multiplier can snap on or off as the level varies. Hence, it is necessary to have some reserve drive in hand. A good minimum is about 3dB above that required to ensure reliable multiplication.

When tuning up a multiplier stage the power output should vary smoothly as the input and output are aligned. If the multiplier snaps on and off as the tuning is altered it is usually a sign that the input drive level is marginal. A good check of this is to measure the base voltage of the BJT with full input drive. If the drive is adequate the base voltage should be a voltage slightly negative with respect to ground. A value of -0.25V to -0.75V is normally about right. When the input drive level is more than required the top potential divider resistor in the base bias chain can sometimes be omitted and the drive develops a negative base voltage across the base to ground resistor. In cases such as this it is prudent to connect a reverse biased diode across the base to ground to clamp the base reverse voltage to less than 0.7V to protect the base-emitter junction.

Fig 8 shows the spectrum for a multiplier stage where the input drive level has been deliberately reduced to show the effect that instability causes.

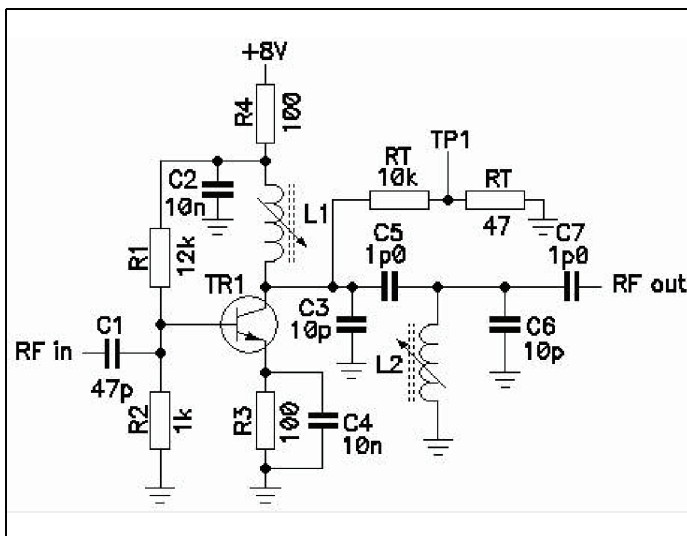


Fig 9: Test point added to multiplier stage.

6.

Optimum Supply Voltage

In all the years of designing frequency multipliers using BJTs it has been found that there is a certain range of supply voltage where the optimum performance occurs. It is not quite clear why this is so but is probably to do with the inherent parametric varactor diodes in the BJT. However, from many experiments the optimum supply voltage on the collector-emitter junction is about 7 to 9V, the so called “sweet-spot”. With voltages far from these limits the efficiency suffers, with too low a voltage the power output falls away and with too high a voltage the efficiency also falls off. Hence, when designing a multiplier chain using BJTs it is often best to use a supply voltage of 8 to 9V. This is convenient as a 3-terminal regulator can be supplied by the nominal 12V-vehicle supply.

If the drive level into the next stage is too high a simple cure is to starve the inter-stage buffer amplifier transistor or MMIC following the multiplier by in-

creasing the collector feed resistor value to limit the collector voltage.

7.

Choice of Transistor Type

As strange as it may seem we do not need to use a “super-transistor” for an efficient multiplier. Often the choice of a transistor is dictated by the frequency of operation and hence the f_t as an amplifier needs to be quite a bit higher than the operating frequency. This however is for a transistor operated as a linear amplifier, when used as a highly non-linear multiplier we can often get by with less exotic devices.

From experiments made on a wide selection of transistor types it has become apparent that even lowly devices such as the 2N2222 with an f_t of only 100MHz work perfectly well up to a few hundred MHz when operated as a doubler or tripler stage. For the frequencies higher than this a move to a popular type such as the MPSH-10 or the BFR92A or

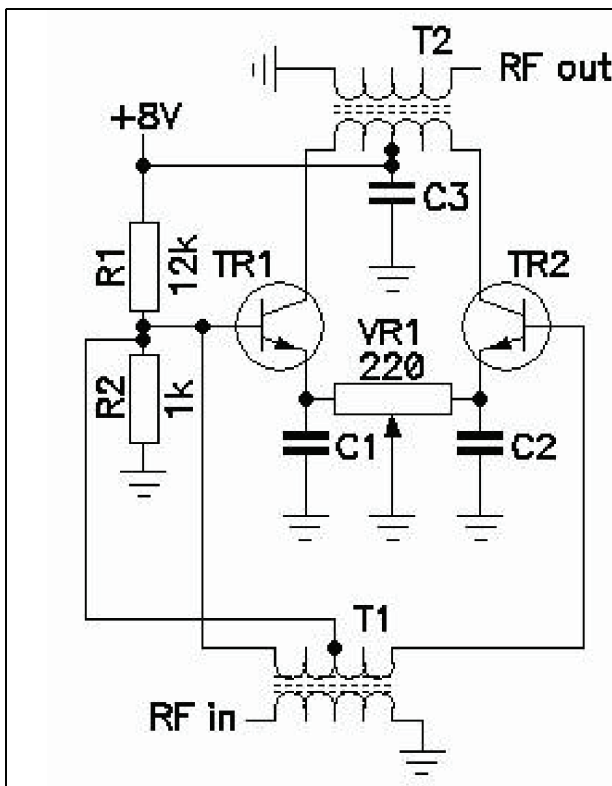


Fig 10: Push-Pull doubler.

BFR93A in the SMD SOT-23 package work well even as high as 2GHz, which the manufacturers data does not suggest. Of far more importance is the drive level and the filtering components used to select the wanted harmonic. If the filter has excessive loss then the advantage of using an exotic transistor is wasted.

8.

Test Points

When aligning a multiplier chain it is helpful to be able to break into the chain at critical places to attach test equipment to see what is going on. Some designers make all the multiplier stages to termi-

nate in 50 Ω so that normal test equipment can be connected. This not only introduces extra loss but also adds unnecessary components to the circuit. We can safely assume that the base input impedance of a typical BJT when driven at the optimum level is about 200 Ω to 500 Ω . Therefore the drive power is not going to be too high; perhaps +10 to +13dBm in 50 Ω when transformed up will give sufficient base-emitter voltage swing.

Probing a high impedance portion of the circuit with a RF AC voltmeter often causes detuning because of the probe capacity. A simpler method is to incorporate some test points where a 50 Ω instrument can be attached without breaking the chain. Often two resistors can achieve this and the 50 Ω equipment can be attached as and when required without upsetting the system. This con-

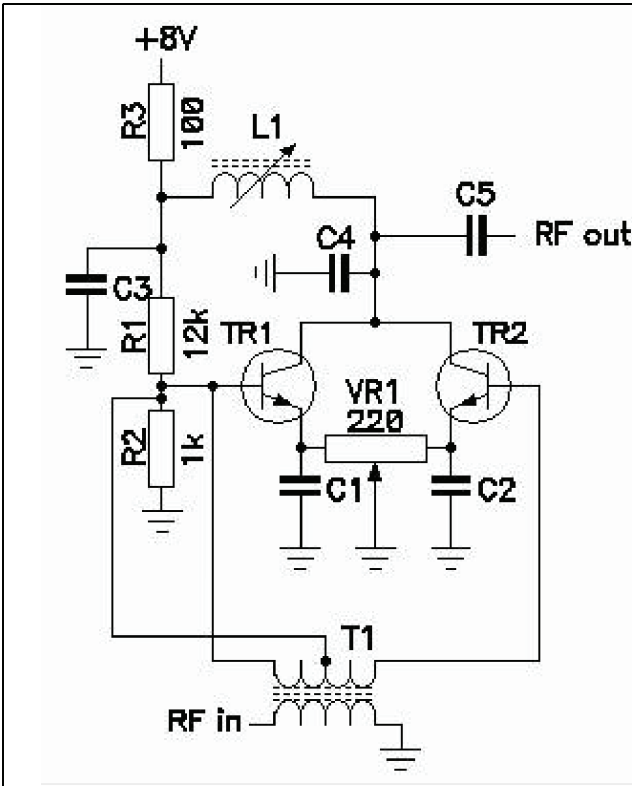


Fig 11: Push-Push tripler.

cept is illustrated in Fig 9. The two resistors are a high value one to tap into the high impedance point and a second termination resistor to suit the test equipment. A coaxial cable can be connected and taken to a spectrum analyser to see the spectrum. The amplitude will not be correct but the spectrum should still be the same.

9. Using MMIC Amplifiers as Multipliers

There have been several application notes and other articles published concerning the use of wide band microwave

monolithic integrated circuit amplifiers (MMICs) as frequency multipliers. The choice of devices is somewhat limited but several writers have reported good results. However, because of the internal biasing components of typical MMICs these devices do not really lend themselves to this application. Whereas it is true that any transistor can be over driven to force it into a non-linear operating portion this seems not so easy with the typical MMIC. As the typical MMIC is designed to interface with 50Ω terminations intuitively we can see that we cannot run the collector into the high impedance necessary to induce the varactor diode effect.

Where MMICs can be made to work is with an external shunt diode across the input, with DC blocking capacitors to prevent the bias being upset, to generate

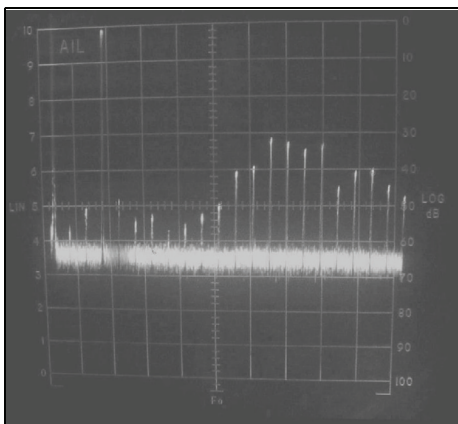


Fig 12: Wide band sweep of LO signal.

the harmonic energy and then to use the MMIC as a conventional amplifier to raise the level. However, when you run the calculations of the total power required the efficiency still ends up being quite low and a cheaper BJT will probably out perform it at far less cost. MMICs are good as inter-stage buffer amplifiers but not so good as multipliers.

10.

Special Multipliers

Where we need additional suppression of certain harmonics we can utilise some of the ideas found in diode multipliers. Fig 10 shows a push-pull doubler using two BJTs. The circuit suppresses the odd order harmonics by about 30dB and leaves just the even order harmonics. The variable resistor VR1 allows the circuit to be balanced by adjusting the emitter currents of TR1 and TR2. This provides the best null to the unwanted products. For optimum performance a dual-transistor in a single package offers the best results.

The wideband transformers T1 and T2

need to be wound for the best balance and this limits the higher frequency performance.

This circuit can also be modified to form a push-push tripler where the predominant harmonics are the odd order ones. This is shown in Fig 11.

11.

Multiplication Order

In many cases we need to multiply by a fixed number and this is clearly defined by the starting and finishing frequencies. For example a receive-converter for 23cm may require a 24x-multiplier chain to arrive at the final LO injection frequency. A 24x-multiplier can be arranged in several different ways. We need to multiply by 24, which can be broken down into doublers, triplers or quadruplers (2x, 3x or 4x). Choosing which multiplier factor to use and where in the chain is often not simple. As a general rule it is often better to make the first multiplier stage with the greatest multiplication factor, so in this case we might choose the first multiplier stage to be a 4x. Against this must be weighed the difficulty of filtering out the harmonics close to the wanted multiplier product.

As an example, consider the 23cm receive-converter for an IF of 144MHz. The starting frequency is 24x less than the LO injection, which in this case is 1152MHz. This determines the crystal frequency as being 48MHz. This is a good choice as the 3x product is 144MHz and if a test port is provided on the first multiplier then a small amount of the 144MHz signal can be used to set the band edge on the 144MHz tunable IF. If the 144MHz receiver is accurately calibrated in frequency readout the receiver can be used to zero beat the crystal



oscillator exactly onto 144MHz. Hence, in this case the first multiplier needs to be a tripler.

However, consider the case where the filtering of the first multiplier is insufficient to reject all the 48MHz spaced products. If these are allowed to pass through the subsequent multipliers then we will end up with 48MHz products spaced either side of the final LO frequency. The 1152MHz product is not of concern but the image at 1008MHz (288MHz away) will cause degradation in the receiver performance.

Hence, it is better to first double the 48MHz to 96MHz, band pass filter the result as well as possible to reduce the 48MHz products to negligible levels, and then proceed from there. No integer multiplication factor using 96MHz can produce a signal at 1008MHz so this is a better plan.

Assuming we choose the first multiplier as a doubler, this leaves a total of 12x further multiplication to arrive at the final LO injection. Filtering at 1152MHz will require a fairly good filter and to ease the design of the filter we need to place the unwanted harmonic products as far away as possible. We could choose the final multiplier to be a doubler and hence the injection frequency into the final multiplier would then be 576MHz. If this choice is made then we need to assess if it is possible to arrive at 576MHz from 96MHz. The answer is we can by multiplying by 6, this would be a 2x and a 3x multiplier in either order.

If we chose the more traditional route of multiplying by 3 from 384MHz to arrive at 1152MHz then we need a total multiplication of 4x from 96MHz; this could be 2x & 2x in two separate stages or a 4x in one stage. Again we need to assess the difficulty of making a band pass filter at 384MHz that can reject the 96MHz spaced products with sufficient attenuation. The safest method would be the dual 2x approach as the filtering of a 192MHz spaced product with a 384MHz

band pass filter is likely to be easier. This also simplifies the filter design and it is likely to have less insertion loss than the narrower filter previously required. In some cases commercial helical filters can be obtained aligned for the required frequency which allows a more compact design. Companies such as Toko and Temwell list suitable filters in their standard product range that occupy very little board area and these have adequate attenuation to the unwanted products.

Unfortunately not all amateurs have access to a spectrum analyser to ascertain if the multiplier chain filtering is adequate. Many constructors have little more than a RF diode probe and perhaps an absorption wave-meter or milli-watt meter to align the multiplier chain. Although it may appear to work satisfactorily it is only when it is examined on a spectrum analyser that the truth emerges, sometimes causing a big surprise! Unwanted products at the final LO of a receive-converter only cause the operator a problem, but if the same dirty LO is also used to mix up in a transmit converter then we are potentially causing spectral pollution to other users. This is not only irresponsible behaviour but probably in contravention of our license conditions. These spurious signals may interfere with sensitive receivers used by other services, perhaps radio astronomy, civil or military communication services and should be avoided for obvious reasons!

One factor which is misunderstood by most amateurs is how clean the LO signal needs to be. If the signal is being used to drive a mixer to down-convert or up-convert then the harmonic content of the final signal is not important, in fact given the correct phase relationship a bit of 2nd and 3rd harmonic content can be beneficial to the following mixer. The following mixer will regenerate the harmonics of the input signal so there is no need to suppress the 2nd and higher harmonics of the LO signal. What is of far greater importance is to eliminate as far as possible the lower multiplier prod-



ucts especially the ones closest to the wanted LO frequency.

To illustrate the problem take a look at Fig 12. This is the tripler circuit shown in Fig 7 but with the spectrum analyser sweep increased to cover up to 1GHz. Although the products close to the wanted 150MHz are acceptable the far out products around 700MHz are very bad. They are barely 30dB down and are due to a poor layout where the harmonic energy was able to hop over the filter and get picked up in the output amplifier stage. A contributory factor is the topology of the band pass filter; it is a top-coupled design and hence tends to act like a high pass filter to the higher harmonics. If the spectrum analyser sweep had not been opened up we would be blissfully unaware of how bad the spectrum was. With the writer's spectrum analyser covering from 10kHz to 12.4GHz it is possible to see significant levels of harmonic energy all the way up to nearly 3GHz. This is with a transistor "officially spec'ed" only to an f_t of 650MHz.

If significant levels of spurious signals at the LO exist then these are potential interference generators for frequencies far removed from the wanted channel frequency. Most microwave receiver front ends do not have very high selectivity because of the nature of LNA design; few LNAs have anything like the required rejection characteristics because this would destroy the low noise figure required. If the unwanted signal is of sufficient amplitude to get past the front end filtering and into the mixer then these will appear as "birdies" or "sprogs" when the receiver is tuned across the band. If you are really unlucky then you may find that your weak signal DX channel is completely obliterated by a strong signal far from the wanted frequency. Running some simple mixing spurious calculations can highlight potential problem areas.

The choice of the 1st IF and hence the

LO frequency can have a dramatic effect on the image and other spurious response characteristics. If the 23cm band is used as an example then the choice of 28MHz as the 1st IF is not a good choice. For this we need a LO at 1268MHz and the image will then be at $1268 - 28\text{MHz} = 1240\text{MHz}$ which is right in the middle of the aeronautical DME and radio altimeter band worldwide! Typical radio altimeters are downward looking radar systems fitted to most aircraft and these radiate up to 10kW of pulsed power. DME systems are used for distance measuring and the aircraft radar interrogates a land-based transponder, this then sends a reply pulse delayed by a known amount. By measuring the time delay the aircraft can calculate the exact distance to the ground transponder. A typical aircraft DME transmitter is about 300W and the ground station anything up to 10kW.

The writer recently had to do a significant system revision for a radio telescope receiver for the Hydrogen Line at 1420MHz that is under development. It was originally proposed to use a 1280MHz 1st LO and the 1st IF was at 140MHz. Only recently it became apparent that a significant amount of L-band microwave signals on or near the image frequency of 1140MHz from aircraft DME transponders existed with high signal levels caused severe interference and this forced a change in 1st LO and 1st IF. The 1420MHz receiver has only 40dB of image rejection because of the nature of the LNA and front-end filter design to obtain the required sensitivity. The minimum discernible signal of this receiver with the LNA noise figure of 0.18dB is less than -146dBm , which is about 20dB better than a good 23cm receive converter. In this case it was found that changing from a "Low-Side" injection scheme to a "High-Side" injection placed the image frequency at about 1700MHz which is also a protected portion of spectrum reserved for SETI research and the 1st IF then occurred at 152MHz which is another protected piece of spec-



trum for Radio Astronomy. The 1st LO then occurred at approx. 1572MHz.

12.

Special Local Oscillator Techniques

During the upgrade to the writer's 23cm transverter an unusual approach was used. The original design used a 5th overtone crystal at 96MHz, but this suffered from excessive warm-up drift and other problems. Because the desire was to make as little change as possible it was decided to make a new 96MHz oscillator module that then fed into the existing modules. This new module used a 12MHz TCXO, which was multiplied up to 96MHz, a factor of 8x. The first multiplier used a 2x and the second a 4x. After filtering and amplification the 96MHz signal was fed to the original oscillator multiplier chain. A test port on the second multiplier provided a small amount of 144MHz harmonic energy to calibrate the 144MHz transceiver.

Because the first multiplier output spectrum contained products spaced 12MHz and 24MHz either side of the wanted frequency the filtering required was quite severe. If these products are not removed at the source then it is practically impossible to eliminate them further down the multiplier chain. The aim was to attenuate these close-in products by at least 70dB, in the end a figure of over 80dB was achieved by careful attention to the early band pass filters. The 96MHz final output was clean; the worst spurious product was -86dBc, which was considered sufficient. Filtering, shielding and supply line bypassing achieved a compact and clean module suitable to drive the existing multiplier chain. One of the other problems with the 96MHz crystal oscillator was its susceptibility to strong

RF fields when transmitting 250W on 23cm. This caused FM when using SSB or a chirp when CW was used. With adequate shielding and supply line bypassing these problems disappeared with the new oscillator module.

It must be appreciated that the filtering inductors need to be well shielded, the best option is pre-wound canned coils or helical filters such as those made by Toko. If air wound inductors are used the coils radiate spurious energy and this can hop over shielding plates and effectively bypass the filter. The RF voltage at the collector of a multiplier stage can be many volts, and these make good "mini-transmitters" unless the RF field is contained in shielded compartments. Grounding, layout and shielding are all vital parts of any oscillator chain design and construction.

13.

References

[1] EB-70A "Frequency multiplication simplified by internal faraday shields in MRF629", Motorola Semiconductors

HEROS technology Ltd

www.herostechnology.co.uk

- WinPIC2006 USB full speed programmer.
- CPU microcontroller modules.
- Peripheral modules for all microcontrollers.
- RF components.