# Dual 70cm and 23cm Dish Feed

*by Doug McArthur, VK3UM*

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## Background

Over the years there have been numerous designs to provide dual band operation and most followed as a 23cm feed, the W2IMU design. The 70cm feed nearly always consisted of two sets of dipoles arranged in an 'H" configuration which were then switched to provide horizontal and vertical polarization essential for 70cm EME operations. It seemingly was assumed that the dipole impedance in this configuration was about 72 ohms. This was transformed by a transition and multiple quarter wave sections of 72 ohm cable to provide a theoretical 100 ohms. When two of these dipoles in this configuration were connected together in a 'T' the resultant impedance was expected to equate to 50 ohms. With the advent of the VE4MA design it now provides adjustable illumination for dishes in the f/d range of 0.25 to >0.6. In my case, having a 0.43 f/d dish the best illumination would have been achieved by following the VE4MA design but due to the size of the opening it would require the 70cm dipoles to be placed inside the launching ring. Some said it made little difference in performance but I believed degradation would have to occur on both bands. Many operators have taken the easy way out by physically changing their optimized feeds as required. This is certainly the best (and only) way to retain optimum performance on both bands but the physical effort to change the feeds quickly has, I believe seen a decline of stations on 70cms.

## Is there a realistic compromise option?

For several years I resisted the proposition to leave 70cm and concentrate on 23cms and although I built a VE4MA feed, which would have provided optimum illumination of my 28ft 0.43 f/d Kennedy dish, I could not entertain the permanent loss of 70cm. I then decided to attempt to build a compromise system that would retain both bands.

The first decision was the easy decision, what feed to use on 23cms? The W2IMU horn was the obvious (and only) choice as the interaction between it and the 70cm feed system should be minimal as the dual dipoles could be arranged in a similar way without impinging significantly upon the 23cm feed. The negative side to such an approach was that the pattern from the W2IMU would under illuminate the dish. It has long been considered that an optimum feed would illuminate the dish with a -10dB taper at the edge of the dish. A 'low noise' dish would have this taper point at about -13dB but in my case I was looking at an edge taper close to -15dB. This meant, in simple terms, that my 28' dish will have shrunk to about 24 feet! However, given the gain of the dish, and the resultant lower received noise temperature, indications were that under illumination in this case would actually provide an increase in actual overall performance.

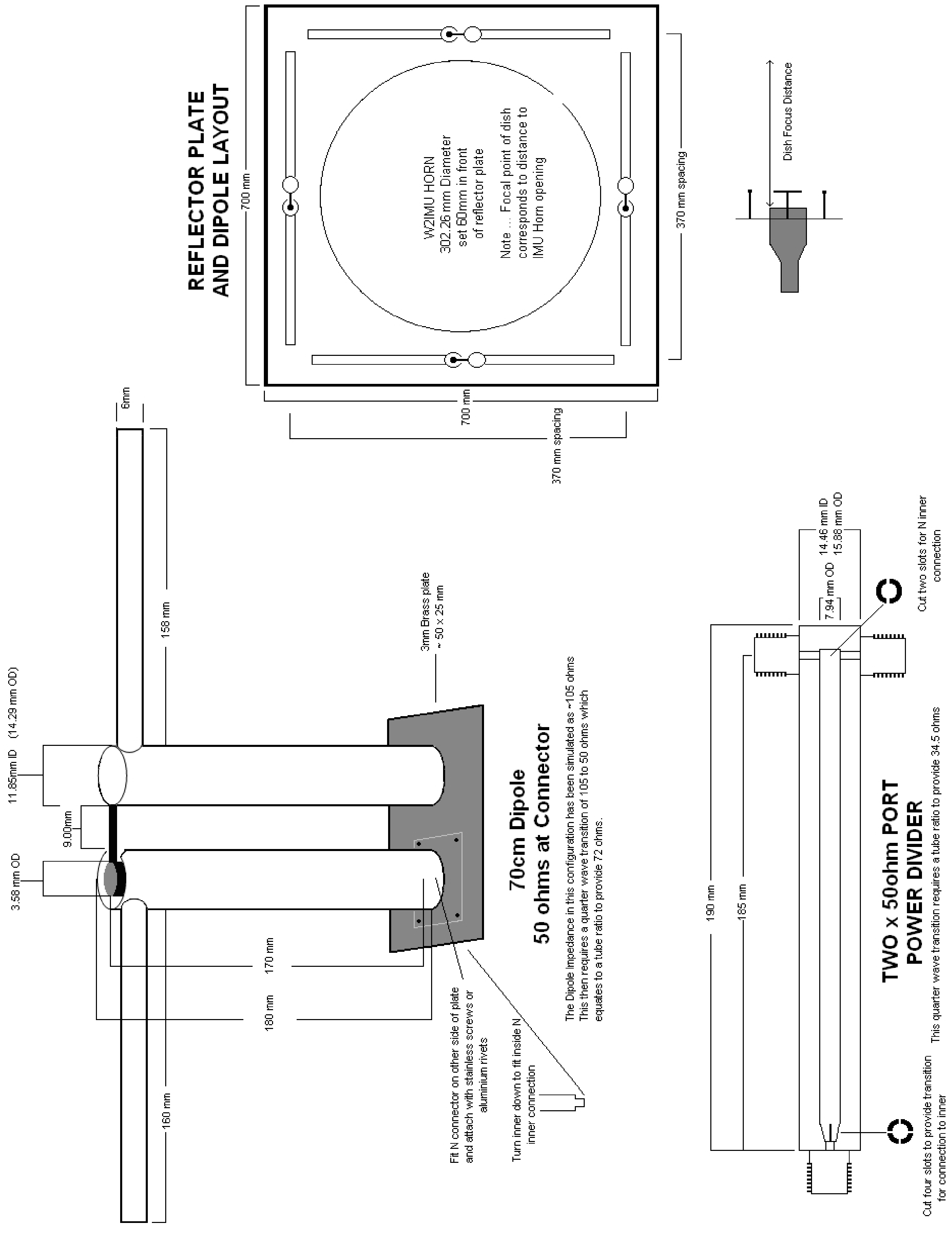
For a long time I wanted to redesign the 70cm feed but the prospect (having retired and not having a network analyzer at my disposal) of getting the phasing exact with my limited test equipment was daunting. What I knew I could have done in a day would now mean days of cut and try, something that all failed retirees would understand only too well!

My objective with the 70cm design was to achieve as close to a 50 ohm zero j impedance at the splash (reflector) plate for each of the dipoles. Having achieved that, then by the use of two way power dividers the ultimate match, and lowest loss feed could be achieved without the use of the notorious and seeming impossible to achieve quarter wave matching sections.

The idea is far from new and Geert (PA3CSG) for one, has used a similar technique and with Graham (F5VHX) simulation calculations (confirmed independently by David VK3AUU) the real dipole centre impedance calculated was in fact ~105 ohms. This was the key factor to the whole re-design. Previously 72 ohms was seemingly accepted as the value. The implementation was going to be a challenge without a network analyser but if the calculations prove correct in reality then it should not be too hard to implement.

## The 70cm Dipole configuration

Before I go further, this feed system by simulation, also does not fully illuminate a 0.43 f/d dish, and the theoretical taper is ~ -13dB. This results in a lower than optimum gain but provides a lower effective




# VK3UM 70cm and 23cm Dual Feed System

**Not to scale**

receive noise temperature. Again like the 23cm feed this was not considered a negative and besides I had been using it unknowingly for years! The only way to fully illuminate the surface is to move the dipoles closer. As the dipoles are as close as practical anyway, bending the ends of the dipoles could be an option. I considered it 'too messy' and likely to add possible unforeseen problems.

The accompanying drawings provide the dimensions that are required to duplicate this design. Importantly the transformations required are shown. It will help to use my software (ZCalculator, which was written during the course of the project) as you will surely find that the tube sizes are not available. Choosing the best combination is simplified by use of the software. Invariably you will most likely have to turn down the inner.. (refer www.sm2cew.com) Ironically, I brought home from the US a stack of hobby tubing for this very purpose only to find the locally available sizes were more applicable!

The key, is the 105 to 50 ohm transformation (72.5 ohm transition) and what ever tube/rod you can obtain, this ratio must be maintained. The inner rod or tube becomes the difficult area of construction where 'near enough' is really not 'good enough'. I have a lathe but my initial attempt to accurately turn down the available rod to that calculated was a disaster. I did not have a 'steady' and required help from an expert. Enter Bob (VK4XV) builder of steam engines and all things mechanical who saved the day. He was most apologetic when he said he could only get it down to 0.02mm accuracy over 170mm and would that be acceptable! Well that was good enough!

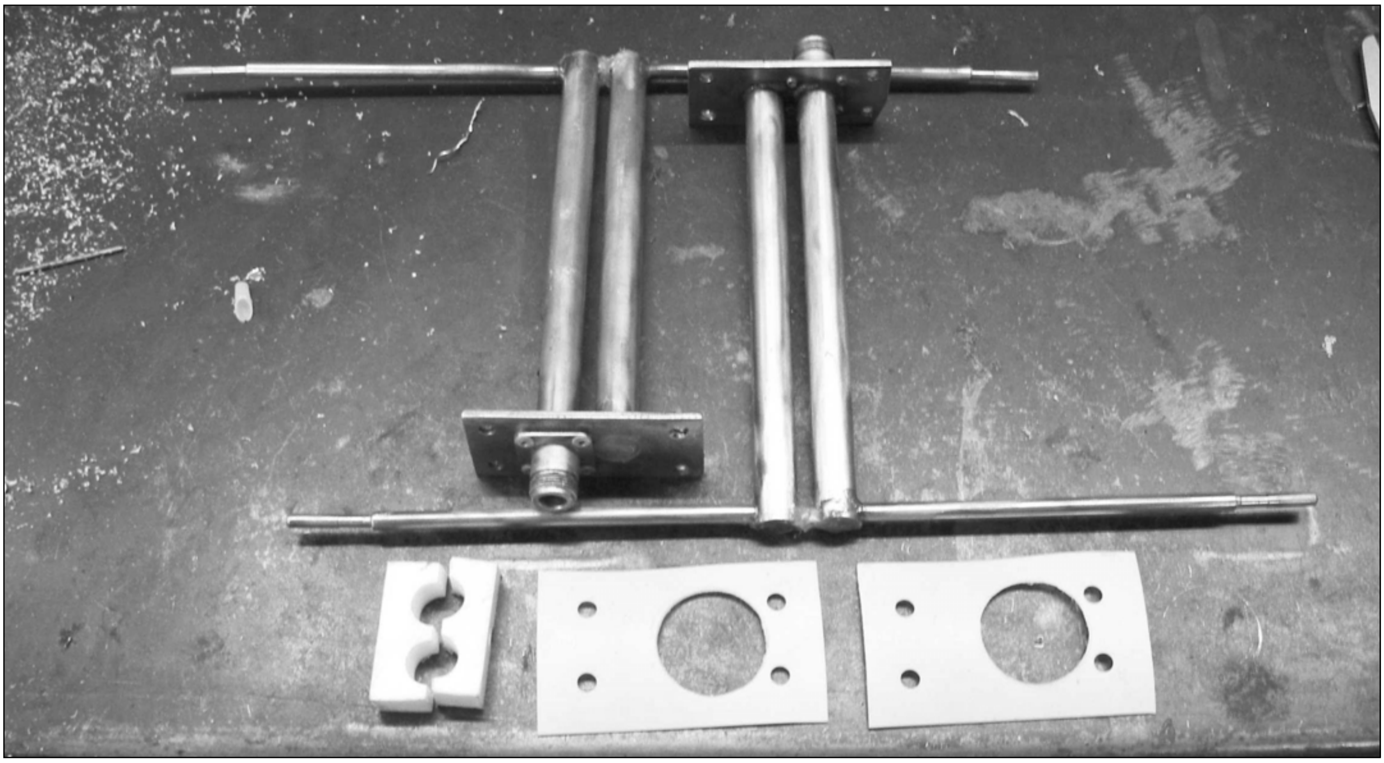


**Photo 1: Two dipoles with PTFE insulation sheet and dielectric shorting stub (not used) prior to mounting on splash plate**

## Test Equipment

My 'test equipment' consisted of a Icom 910H, Bird watt meter, (with a 5 watt slug), a home built impedance bridge (copy from RSGB VHF/UHF Manual 10.17 modified with SMD c's and r's for a better balance), MFJ-269 Analyser ( I was disappointed .. to put it politely .. when I found that Z measurements ceased at 150MHz .. they don't spell that out!) and a 6dB through line attenuator used to reduce the minimum power of the IC910H to that suitable to drive the impedance bridge. I also used a HP141T spectrum analyser for the port isolation measurements. Last but not least, a digital set of vernier calipers with selectable metric/Imperial is pretty well essential for those with less than 20/20 vision.

## Test Range

Initially I set up a wooden bench outside in the clear but it did not take long before the summer heat became just too much and I moved the bench back inside a large 20x10x4 meter metal walled and roof

Farm shed. Yes there were reflections, but I found that pointing it a certain way inside the shed to I could reciprocate the ‘outside readings’. I resumed my fabrication inside the shed. The final result, when tested outside again proved identical … and I avoided a dose of sunburn! I only raise the aspect of the test range as you can with care get away (like I did) without the requirement of a ‘purists outside test range’. It makes for a more pleasant working environment!

## The W2IMU horn

Nothing much to add here .. just follow the dimensions and build it! I was most fortunate as a local farmer had a roller he had not used for decades that worked just fine. Finding it under his junk in the ‘workshop’ proved the biggest challenge! Tuning it, well that’s the easy part. Having followed Graham (F5VHX) escapades in meticulously setting up of a test range, building and testing helixes and spending a frustrating week or more adjusting, tuning and proving the resultant measurements to be circular, he then measured the final derived settings and found they were so very close to the published design data !! I set them to these figures. Done!

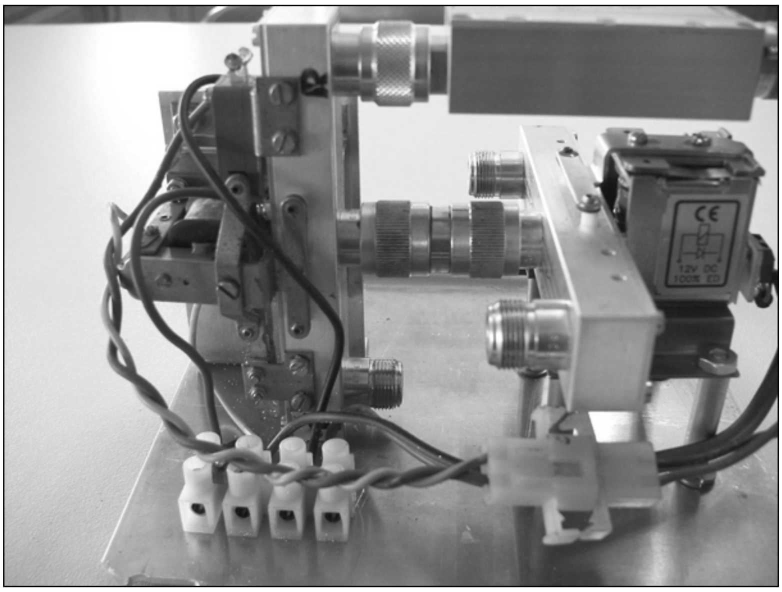


**Photo 2: HF400 Transmit and polarity switching relay configuration before fitting in enclosure**

**Warning.** *If you require additional power when checking the return loss or port isolation on 23 cm be aware that the <u>safe distance for 50 watts into the horn will equate to 2.01 meters</u>. Do not look into the horn or ‘be out front’ when power is applied. If you have to get close do so from the rear. Refer my EMRCalc program for further information.*

Yes I did check each of the probes for return loss and found that is was not ‘special’ but after varying the length and diameter of the probes I found I still could not do any better and went back to the published dimensions. I did not add the polarizing screw as I measured > 25dB between the ports which I felt was good enough. (Measured with the HP141). I had the whole horn silver plated. It was quite inexpensive and admittedly an over kill but I can now watch it go black instead of green! I then lacquered the outside with the special outside acrylic lacquer ‘guaranteed’ to resist UV (24 hours?) and covered the opening with 1mm PTFE (Teflon) sheet. This is held in place by two ‘in series’ hose clamps. Get two the same as you can bet the treads will be different on other sizes. Mount the horn as shown on the splash plate protruding 50mm forward.

*This is the actual focal point that should correspond to the dish and this point also corresponds very closely to the dipoles focus as well.* Final positioning in the dish may be necessary and will be explained later.

## Hints and ideas

I used soft solder through out the construction of the power W2IMU, dividers and dipoles. Silver solder would have been a better option but the cost of gas bottle rental in this country is exorbitant and the extra heat, where necessary, was obtained from the trusty propane gas bottle. I also have a very large 250W electric soldering iron. Admittedly one needs to be an octopus when working on the IMU.

During my previous construction I had mounted the brass dipole plate to the aluminium splash plate with aluminum rivets with so called carbon impregnated aluminum conducting grease. Wrong! I knew it at the time that corrosion/electrolysis would be a problem but after 4 years was far worse than I ever expected. Answer. Use PTFE (Teflon) sheet between the plates and attach with stainless steel screws. (Peter G3LTF’s suggestion). If you want to use aluminium rivets be aware that the common hardware variety have ferrous heads and the expanding pin/head will rust ... knock them out after fixing to avoid this rust problem, or use aircraft quality rivets if you can get them. (Dave G4RGK’s suggestion).

I also made up a jig to hold things in place whilst soldering. It took some time and effort but not every one still has retained the same dexterity of their youth .. and they all turned out the same!
I suspect that the length of the dipoles could vary a little if you don't use the 6mm tube. Initially I had screws in the end of each which I could vary to obtain the best match as shown. It took quite some time as was not as simple as one would have hoped for there is significant interaction between the dipole ends. When I finally got the lengths correct I replaced the screws with brass rod inserts turned up on my lathe. I also made a set of PTFE dielectric tuning (shorting) stubs on the assumption they would most likely be required for the final tuning.

I have tried many types of sealant to seal the ends of the dipoles. I have as yet to find something that is truly inert to brass and does not leave a tell tale green verdigris mark. It really does not matter too much as the weather seal is the important part. Choose an inexpensive one from your local hardware store 'non corrosive, UV resistant and water proof, suitable for roof and rain water systems!'. Previously I had used Dow Corning 732 (brilliant for corona suppression in high power RF amplifiers) but that too is also corrosive to a minor extent, and expensive. I did several experiments to see if there was any un-toward effects upon the tuning. Yes, slight, not as much as I first thought. Use only as much that is required to seal the very end of the dipoles to keep the dielectric constant change to a minimum. Watch carefully around the bridging strap to get a total seal. Use a moistened finger to form the sealant into a smooth continuous finish.

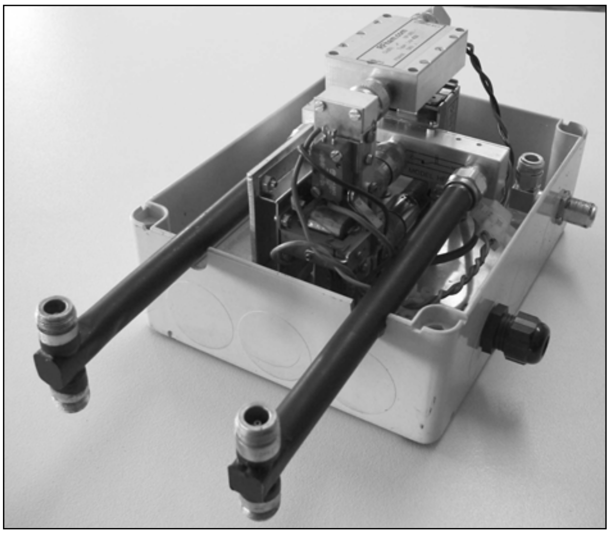


**Photo 3: Power dividers, Polarity, Tx Rx switching and Preamp enclosure**

## Checking each Dipole

Mount all the dipoles on the reflector plate. In the beginning I used a six wavelength length of LDF4-50 (measured as below) to isolate myself from the proximity of the splash plate. I soon found that that was not essential as I connected either the Bird Wattmeter and/or the MFJ-289 directly to the dipole under test. The primary adjustment was the length of the dipole and I was able to monitor simultaneously adjacent pairs and thus see the interaction between them. It took a while to arrive at the dimensions given and I would expect minimal adjustments will be needed in you case if you follow the given lengths. You should expect to see figures with the Bird of 50 watts forward < 0.3W reflected or a VSWR of about 1:1.15.

**Warning.** *If you need to run power when checking for return loss on 70 cm be aware that the* *<u>safe distance for 50 watts into the dipoles will equate to 2.5 meters.</u>* *If you have to get close do so from the rear. Refer my EMRCalc program for further information.*

I found it interesting, (but probably obvious when thinking about it) that whilst the dipole lengths were not exactly resonant, moving your finger up and down the transition would enable you to obtain a perfect match (on the meter). Don't be tempted to replace your finger with a mechanical one as you can do better! As you progress to obtain resonance the effect disappears and the previously constructed dielectric stubs were consequently not needed. (I was using the MFJ-269 not RF at the time!). Not having access to a Network analyser to accurately measure the impedance and j I cannot be sure it is exactly 50 ohms (with little j), but the way it behaves leads me to believe it must be close (as predicted by simulation). Adding random lengths of 50 ohm coax consistently indicated the same (or so very close to it) return loss further confirming theory with practice.

## Cutting the phasing sections between the dipoles and power dividers

What ever coax you choose as your connecting cable, the precise dimensions can be quickly obtained from ZCalculator. In my case I chose LDF4-50 to keep losses to the very minimum. The length is best kept to a multiple half wavelength. This is not totally necessary as equal lengths would suffice but I preferred to keep what ever the final Z was at the dipoles transformed to the input of the power dividers. In this case, with the configuration shown, it required a full wavelength to reach the two way power dividers comfortably. (It is a tight fit but it works out fine). These ~600mm lengths can be 'artistically bent' and positioned as per the photos to match the positioning of the power dividers and polarity switching box. It was positioned to provide equal balance and distance to all four dipoles. This is not an easy task and I would suggest bending a length of scrap cable to ‘practice’ and form a template. When you are finished you will agree that it looks so very pretty that it just has to work! I finally sealed each connector with heat shrink tubing and when in situ covered this with Denso Tape (waxed tape). Our cockatoos (birds with big beaks and an affinity to anything chewable) are not partial to this type of tape.

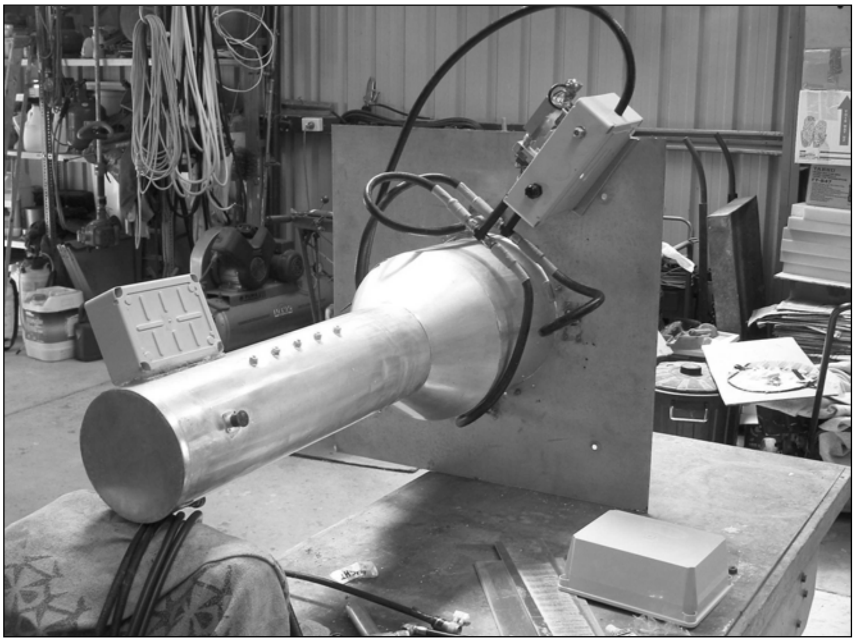


**Photo 4: Cabling Layout betw. dipoles & power dividers**

To cut the cable length exactly, the first will always be the hardest! If you have not had recent practice terminating LDF4-50 connectors then you are in for a refresher course! Fortunately they are a lot easier than most and some what forgiving if you do happen to make a mistake. Don’t put the ‘O’ rings in place until the final assembly .. and then don’t forget them either! Terminate one end and then mark out the calculated distance plus about 10mm. You will find the length very critical to the point where a few file scrapes are only needed to get it exact. It is best to start with a ‘test length’ so that you can get to know your impedance bridge and what you will see at resonance.

You can choose the open circuit or short circuit method and you will really need to ‘go through’ the resonant point to get the ‘feel’ and the actual reading on the Z meter. I preferred to use the open circuit method as I could see the effect with each stroke of the file. It all depends upon the balance of your instrument and once you know when to stop you will be in business! Now you have a length of cable with a connector on one end and an end waiting to be terminated …. I used Andrews’ connectors, which may not be the same as yours and even then there are different models of the ‘same’ connector, so to provide you with a simple way of terminating the final connector and retaining the same electrical length will naturally vary. Take your time and ‘work backwards’ from the added length of the inner to determine just how much to dress back the cable. Chances are you may not get it right first off and have to start all over again. Once you get one right you can then pull it apart again and duplicate all the 3 remaining cables. Granted it can be frustrating but in the end you can achieve a result that is within a degree or so with the simple equipment described. Remember it will end up as a tip to tip measurement. Purists’ will debate this too, but I was not cutting a 6” hard-line feed phasing line to get a precise 1 degree tilt on a 64 bay TV stack as I often had to do in my previous life! Probably you should be looking at a length 2 times less than the tip of the Type N connector inner .. but that’s just too hard to do in a practical sense, and its just really not necessary on 70cms.

## The two way Power dividers

Just fabricate them as the diagram describes. They are not too critical but again try and get the transformation ratio dimensions as close as possible. Cut four hack saw cuts on the inner end that goes to the single connector and then enlarge the cuts with a small flat file. You can then carefully crush the end to form a taper to fit the inner of N connector. At the other end, cut a single hacksaw cut and then enlarge with a small flat file to accommodate the opposing N connectors. To provide a flat surface, onto which I soldered the two N connectors, I inserted a square metal block (tapered on the end for gradual insertion) just larger than the diameter of the tube and applied generous heat to the brass tube. Then gently (and very slowly) hammer home the block. This transformed the round tube to a square end section for easy mounting of the N connectors. With care and patience you won’t split the tube. (well not too many times!) It pays to do the ends first before cutting the tubes to length as Murphy will surely cause one to split! Next check the validity of two terminating resistors. You never know, you may have hit them with too much goo at one stage, and they may not be in the best of health! Then finally check the power divider by terminating each input port with 50 ohm resistors. When using the MFJ 269, you will see a >30dB return loss.

## The polarity switching and LNA box

Again a picture tells a thousand words. You will see I have used two HF400 relays (one for the polarization switching and the other for the transmit/receive change over) mounted at right angles. I use a separate feed line back to the shack from the LNA output. The LNA is left on all the time and the isolation (provided by the HF400) is adequate protection (>60dB) when running 1500 watts at the feed. (Yes I have an ACMA high power permit!). The construction requires only one M-M connector and the power dividers screw directly to the HF400 polarisation relay as does the LNA to the Rx side of the Tx/Rx relay.

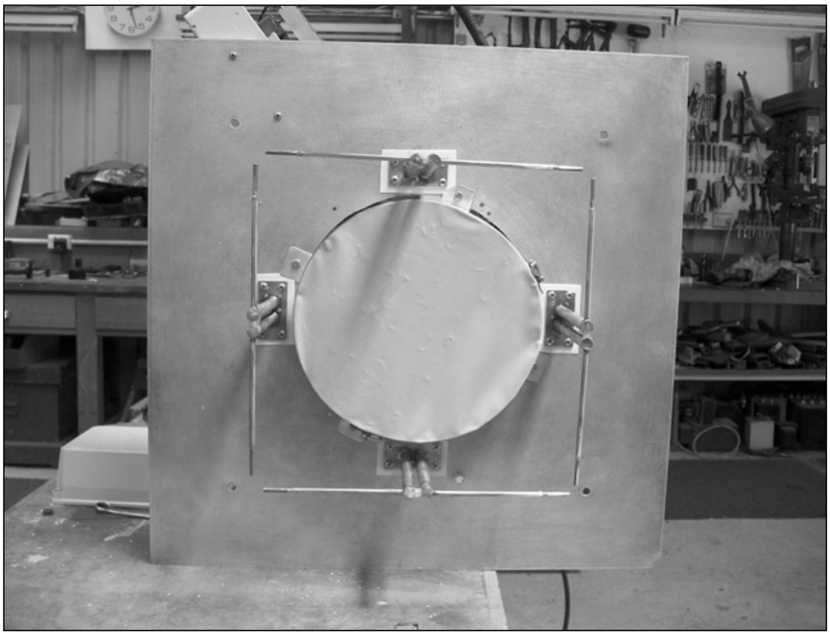


**Photo 5: Front view of W2IMU and dipoles. PTFE (Teflon) sheet covering over mouth of horn**

You can not get a lower loss set up than that !! ?? Weather sealing is done by applying silicon sealant around the Power dividers after each ‘visit’(should be quite rare). No flash plastic bags are used here like some I know! I run separate cables for both the LNA and relay switching with all relays back EMF protected with diodes of course. When I was using my previous cavity LNA I employed a series of regulators starting at 12v to 9v to 5v to a 3.2v zenner. I never had one fail by employing such an over kill method. It did seem good idea at the time!

As an aside my previous LNA and polarity switching configuration consisted of too numerous to mention (embarrassing) ‘T’s’ and bullets that were deemed necessary to achieve an acceptable match. On hindsight it was wrong wrong wrong, but we all do it at times to get going, fully intending to revisit it later and put it right .. which never seems to happen!  The above configuration has provided a significant improvement in achieved receiver noise figure.

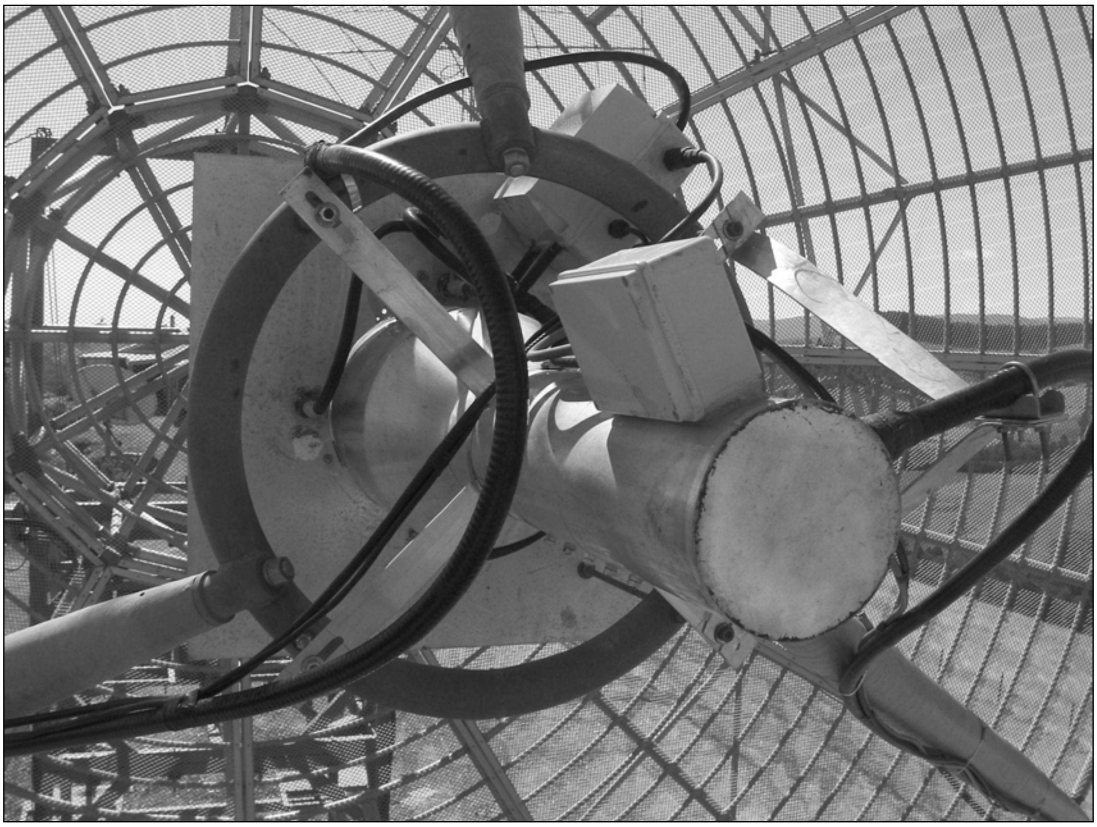


**Photo 6: Feed mount in dish. That mounting ring weighs 25kg!**

## Putting it all into the Dish

I had now reached the stage I feared the most! Mechanically it is a dream to work on the feed from the feed platform and the hardware mounting is rigid in the extreme. I had made provision to be able to move the splash plate back and forth (mounted on four 15mm threaded rods) to accommodate finding the phase centre of the dish. I also paid special attention to the LDF5-50 transmit feeders which would require sufficient slack to facilitate this expected movement.

My major concern was the interaction I had experienced with the previous 70cm feed. This was, to say the least, most profound. I had spent hours raising and lowering the dish and adding those previously mentioned extra bullets and re-cutting and terminating the '75 ohm phasing sections'. Interaction between the dish and the adjacent EME Shack was significant to say the least.

As a first check (I first concentrated on the 70cm feed) I attached the MFJ-269 directly the LNA input on the HF400 and found both polarisation to be so close to the 'test bench figures' that almost made me suspicious! This was with the dish 'over and 2 meters from the shack. I then reverted to applying power to the transmit feeder and confirmed the figures just measured at the LNA. I held my breath as I raised the dish to about 45 degrees, clearing shack, and was delighted (read ecstatic) to find that the return loss actually improved a tad on both polarities. Well that was the 70cm taken care of and attention was then given to the 23cm horn.

**Photo 7: Feed mount in dish**

This too was an anti climax as the return loss was also so close to the test bench figures as well. Again little or no difference to the return loss occurred when I raised the dish. My ecstasy had now reached fever pitch!

The next step was to prove, by noise measurements, that all performance figures were being realized. I quickly checked the Sun noise on 70cms and found it to be within the ball park to what I expected, but upon measuring the Sun Noise on 23cms it was well below (estimated 3dB) what it should have been. (EMECalc). Checking my echo's also confirmed something was far from right and both figures pointed directly towards the feed as they were commensurate with each other. The beam width was measured and found to be very close to that predicted (just under 2 degrees). No side lobes that could be measured. Maximum Sun noise was occurring right in the centre of the dish as confirmed by the shadow and the pattern was seemingly correct in all planes. Still I was down significantly in Sun noise to what I calculated. Thoughts went to what could have been happening with the 15dB taper but that too did not add up. My prime suspicion was that the feed was not at the phase centre of the dish. I then contacted several friends (see acknowledgements below) for their diagnosis and prognosis of the situation!

All reservedly agreed that this was the most likely cause but their thoughts did vary in how much could be gained or lost in the situation. The one thing that was bugging me was that I knew the splash plate was set at the focus and that meant the W2IMU horn was 50mm closer to the dish surface that theory dictated. Would such a 'minor difference' cause such a markedly degradation. I did not think so, but one guy turned out to be spot on. Well I waited for one cool day when the sun was on my Northern side of the zenith (yes some things do go backwards down here!) so as the distance between the feed platform and the Sun would mean minimal dish travel. I expected to do this many times and my hydraulic elevation system is not too fast. First to the Sun and carefully measured the noise and watched it for about 15 minutes to observe any variation. Back to the feed platform and confirmed with a long calibrated plastic pipe that the splash plate was indeed 144 inches from the surface (yes we are bi unitized here too!) I then shifted it away from the dish by 50mm. Back to the Sun and wow! … the missing 3dB had appeared like magic.

I could not believe my eyes but repeating the measurement many times confirmed the significant improvement. The Moon had risen and I just could not wait to check for echo's. They too were now as predicted … and .. the real confirmation .. I was now seeing Moon noise (0.5-0.8dB). No I did not go back and move the feed any more … I should have, but for mine the Moon noise was my confirmation that I was unlikely to do any better.

## On air performance

I could be tempted to say I was able to work this rare un-inhabited rock at 59+ using 5 watts on a winters' day with my Long John M cubed with the cat on my lap, but I will resist such a description of performance evaluation and leave such valued reports to other less salubrious publications.

The acid test of performance was being able to duplicate the predicted values of Sun and Moon noise, as well as noise sources of Cygnus and Taurus. (I can't see Cassiopeia down here as we are too far South and Sagittarius is not a point source). Measuring cold sky to ground (cs-g) is a challenge and a practical impossibility in my case due to my dish being positioned on a ridge line 15 meter wide falling away some 150 meters at 60 degrees. (try walking up it!). As a consequence I thus decided to include a terminating resistor (for 23cm) as a indication of ground temperature.

On 23cm Sun Noise is within ±5 sfu (Solar Flux Unit) of predicted values (VK3UM EMECalc) whilst Taurus measures ~0.6dB and about Cygnus ~1.1dB. My cs-g when pointing at my closest hill some 1.5 km away and noting under illuminating the aperture at such angles, measures about 6.8dB whilst cs/term measures ~7.1dB. The figures do indicate the known difference in illumination.

On 70cm Sun Noise is also within ±5 sfu of predicted values whilst Taurus measures ~1.1dB and Cygnus ~2.3dB. Cold Sky to Ground is ~5.8dB. In both bands, by simply using Sun noise, side lobes cannot be detected (>22dB).

I should point out that my measuring method is far from optimum as I am currently performing it at AF in a USB (2.4kHz) bandwidth in conflict to recommended methods requiring band widths >300kHz.

## Summarizing

In summary the figures do indicate that the performance is very close to those predicted in theory. On 23cm the loss in aperture illumination has been shown to have been compensated by improved noise performance by the figures and the transmit gain loss is minimal and of little consequence given the size of the dish. Any apprehension that performance would be degraded has proved to be unfounded in fact it appears that the net result has been positive.

Finally, there are two points I wish to revisit. Firstly the little or no degradation from test bench to dish of the new 70cm feed when compared with the previous one as well as the lack of proximity interaction with the adjacent structure and, Secondly the significant effect the focal positioning had with respect to the 23cm feed.

I feel satisfied that there is little further that could be done to improve the current dual feed system given the constraints of the dish and to prime requirement to retain the two bands. I also feel confident that the system, if followed with due care, may be duplicated by others with corresponding results singularly or as a dual configuration. The overall 70cm feed configuration is a significant improvement on previous designs and provides a very low loss coupling commensurate with switch able polarity.

## Acknowledgements

During the course of this undertaking many were an inspiration and provided help, ideas and encouragement. The key to the whole project, the modeling and defining of the actual feed impedance, I place at the feet of Graham F5VHX and Geert PA3CSG and with Hannes OE5JFL, Peter G3LTF, Peter SM2CEW, Dave G4RGK, Paul WA6PY, Al K2UYH, and David VK3AUU, all provided a forum of discussion and assistance. W1GHZ's Microwave Antennae book was used extensively as a reference as well.

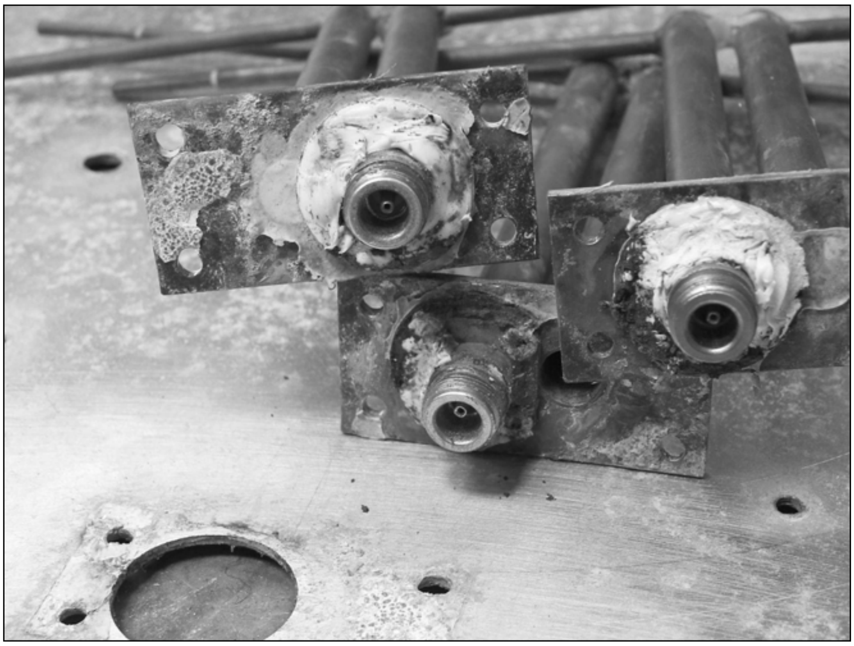


**Photo 8: Corrosion - electrolysis of old feed system after 4 years**

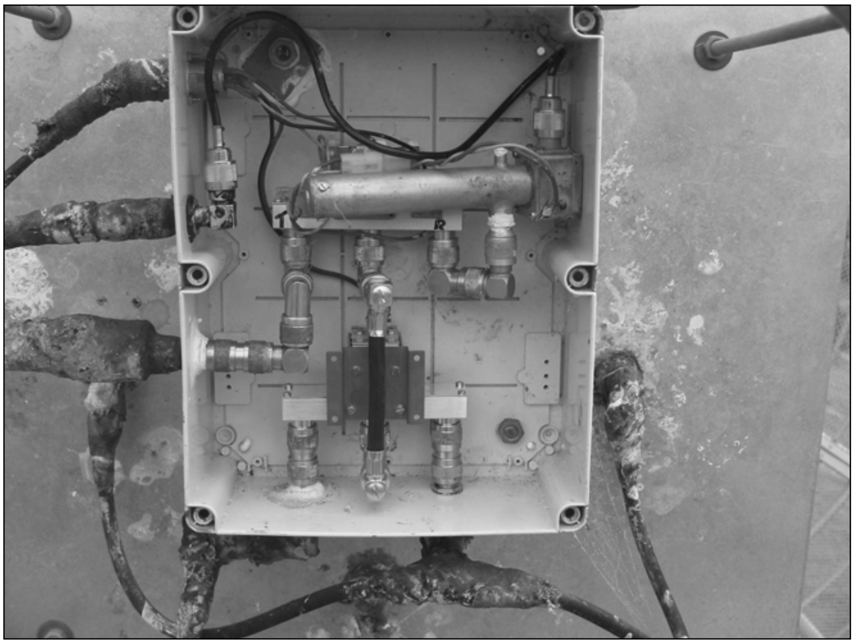


**Photo 9:  Old 70cm system .. note all the connectors! … how not to do it!**