Aircraft Enhancement of VHF/UHF Signals

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About two years ago, Gordon VK2ZAB and I commenced forward scatter tests on 144 MHz between Melbourne and Sydney. The path loss indicated a system gain to overcome -245dB was required. This was achievable with our combined stations. The VK2ZAB station consists of four bays of 9 element Yagis (18.5dBd), 400 watts output and a receiver sensitivity of better than 270 degrees K. The VK3UM station consisted of a slightly higher antenna gain (19.5dBd) and the same transmitter and receiver performance. Combining each station's performance with that of the encumbrant path loss, signals should be received at each end of the circuit approaching 3dB above the noise for better than 90 percent of the time. It was this figure that Gordon and I set out to prove. Probably the time and effort required to verify the text books would normally not be warranted. However as we were both "into the two metre scene" such an effort seemed worthy of the time. Besides the Sydney-Melbourne path had never been worked before on two metres!

Our first tests were very encouraging and although contacts were made the signal levels and reliability was just not as predicted. This however was more due to "what we thought we had" than what we actually were achieving in system performance. Finally when we both got our acts together, presto, signal levels were as predicted!

During our initial tests, we quickly realised that peaks of 30dB or more were evident for periods varying from a few minutes to tens of minutes. It was during one of these "good condition" periods (2130 UTC 1st May 1983 to be exact) that Ralph VK1RK broke on the frequency and almost took the cone out of my speaker! Expecting signals to Ralph to last, Gordon and I continued chatting but when we turned it over to Ralph — *Zilch! No Ralph!* About ten minutes later during another peak in signals to Gordon, Ralph again broke with S9+ signals. This time we did not leave him out on a limb and quickly exchanged reports etc. Without warning signals, which were steady with little or no QSB, started to drop rapidly and Ralph disappeared from the scene leaving Gordon and I communicating via forward scatter with signals about 3dB above the noise!

What caused this strange propagation? The times of the opening seemed to bear a relationship to an aircraft passing between us. A check the next morning positively established that two domestic services from Sydney to Melbourne were mid path at the very times of the enhanced propagation. Actually on hindsight (always a 20/20 vision), Gordon and I had observed this effect on many occasions but the "penny" only dropped when VK1RK appeared on the scene.

The rest of the story is history, but from our hundreds of "scheds" over the last eighteen months our observations may interest others who, under their own unique circumstances, may care to observe and utilise this novel form of communication medium.

It is most interesting to consider the path profile and relate the enhancement aspect that aircraft have on the Melbourne-Canberra path. Firstly the mountainous terrain between the two cities prevents direct communication except at rare times of exceptional trophospheric enhancement.

I have worked Canberra on 2 metres via Sporadic E back-scatter but, between normally equipped stations, ground wave propagation is most restricted by the mountains around Canberra. Knife edge bending is predominant on similar paths, however the angle presented at the Canberra end is most acute and to hear signal levels of those encountered and without any appreciable QSB, was somewhat of a surprise.

I have deliberately coined and used the word "enhancement" as aircraft reflection (off the body of the plane) is seemingly not the actual propagation or reflecting medium. Checking the surface area of the aircraft and noting the exposed area to the signal, the height and distance of the aircraft, combined with what would be the reflected signal level, did not tally with the signal levels received. They were simply too strong. Moreover it has been found that they can vary most markedly given certain weather conditions.

Well, what causes the effect? The aircraft are believed to be the cause and not the actual media of the enhanced propagation.

Candidly I am not sure of the mechanism but offer some possibilities that seem to relate to our observations.

1 Under the worst circumstances enhancement of minimal proportions are present on all transient aircraft and although the signal level increase is small it is always present. This effect will only be noticeable by those stations employing high power, high gain arrays and state-of-art (SOA) receiving systems for the signal increase may only be 3-6dB above the scatter path (Melbourne-Sydney). This effect can be related directly to reflections off the body of the aircraft itself and computes closely with the calculated figures.

2 Reflection caused by the condensation trails (con trails) left by aircraft flying above 30,000 feet.

3 Refraction caused by the air turbulence wake left by such aircraft. (Temperature heating effect or vortex turbulence.)

It is notable that although 2 and 3 are offered as explanations, normal aircraft radar returns indicate (other than the aircraft's reflection) the presence of this reflecting medium is seemingly not evident. This could be explained by the fact that such returns would comprise a back scattered signal or possibly insufficient attention has been given to this aspect. Another explanation could be related to the design of such systems which generally display only moving targets. Nevertheless back scatter does occur and will be related later in this article.

Some readers may wish to ponder the actual cause and pursue this aspect to a conclusion and accordingly there are many additional effects which may assist in the derivation of a more scientific answer.

Ignoring point 1, which would be of interest only to high powered or advanced stations, and complies with predictable data, the latter two (or more?) of extended communication range provide the most exciting possibility to stations of more moderate proportions. Signal levels can be very high indeed (over S9 on the Melbourne-Canberra path) and provide reliable and predictable contacts between the two cities. Predicting such enhancement can be as simple as obtaining domestic air time-tables, however as regular air travellers will know, they sometimes only provide a guide! Fortunately there are simpler and more accurate ways.

Aircraft en route report to ground stations remote linked back to the cities via UHF/SHF bearers. Simple sums will show a line of sight path exists from an aircraft midpath between Sydney and Melbourne back to both cities. Naturally you will not hear the ground station but the aircraft provide saturation signal levels.

It is customary for all flights to report their position at designated intervals and in particular the Sydney to Melbourne aircraft use 128.4 MHz, when overflying Canberra. From this report your can ascertain from the call signs and some knowledge of air carrier information, the type of aircraft and more importantly derive just when the enhancement will commence. Experience, plus a little knowledge of aircraft and airspeed dictates that enhancement will commence about 10 minutes from that time on the Melbourne-Sydney path and 12 minutes later on the Melbourne-Canberra path. These figures relate to my location in Chirnside Park (35km east of Melbourne), VK2ZAB (10 minutes) and VK1BG (12 minutes). Significantly all aircraft do not precisely report their position at this point and variations can and do occur. It can be assumed that Air Traffic Control have all aircraft en-route visually on radar and it does not matter too much!!?? *However we can tell!!*

Another method is by observing what is proving to be a most excellent beacon and a prime example of the application of such a device. VK1RCC is located at Mount Majura, near Canberra and transmits FSK CW on 144.490 MHz at about 12-14 watts output to an omnidirectional horizontal polarised antenna. Not much power you may say, but it can be heard in Melbourne during each aircraft enhancement period. Take a listen to Melbourne stations and you will most likely become fascinated by the effect. Signals will appear from nothing, peak rapidly, hold steady, and disappear into the noise about seven minutes later. Signal levels can be anything from just above the noise floor to S9 on occasions, but are always present.

Application of this beacon is most useful as it provides an indication that propagation exists (or is just about to become available) to Canberra stations depending upon their location. It does however herald the passing of propagation enhancement to Sydney.

The next interesting facet of this enhancement mode relates to the times signals are received at locations that may only be a few miles apart. Although thought to be strange at first, again one should then relate your own and the other station's location, with that of the aircraft. Naturally times will vary and because of the no signal to signal present aspect it will seemingly appear more dramatic. As an example, stations located in the Melbourne suburb of Frankston hear Sydney some two minutes prior to myself. However because of the flight path signals are present for a longer period at my location. Again one should consider the respective incident angles involved. With respect to the Melbourne-Canberra path Eddy VK1VP appears about one to one and a half minutes earlier than Ian VK1BG at my location. It is of interest to note that Eddy's signal from his SOA station never reaches the signal level of Ian's. This is explained by Eddy's location which at the time of best enhancement (critical angle) is blocked by Black Mountain. (6.5 degrees elevation equals -65dB additional loss on a horizon signal.)

Stations throughout Canberra "come and go" at predictable times commensurate with the angles involved. Thus this aspect may prove a little difficult to initially define for your particular location. However given you know each other's location and the flight path of the aircraft or can hear someone from the distant end, you can from this pretty closely predict when signals will be present at either station. At first you may feel despondent upon hearing a station in your city giving the distant station S9 when you are hearing zilch. Don't give up; assuming your system to be performing well you have either just missed or are about to hear the other guy! If you don't hear them well you have problem(s) to solve.

Back to the signal characteristics. As mentioned earlier I was initially surprised at the level and lack of QSB of Ralph's VK1RK signal. *Where was the characteristic aircraft flutter?* Again the penny dropped! The normal aircraft flutter is caused by the multipath effects of signals between the aircraft, ground, and other relevant reflecting objects. In this case the path is direct, and the received angle on the horizon. Consequently no multipath would be present. That explained that one!

It was not long before it became most apparent that the signal levels were not always strong. In fact levels vary up to 60dB under certain conditions. *Why?* It was this fact that (with continued observations) derived the possible explanations given in 2 and 3.

Ian VK1BG has been a most regular contributor and back-bone to our experiments. His unique location in Canberra provides midpath observations and co-ordination with Sydney. Moreover we can always liaise on 80 or 40 metres. Ian, given favourable weather conditions, can usually observe the aircraft first hand. The viewing of condensation trails provides a possible explanation to our varying signal levels. As a sideline to the saga, if he can actually see the aircraft we can predict to within 10 seconds when enhancement will commence. This you can see is most beneficial on the Melbourne-Sydney path where signals are less strong. Thus given this knowledge you are ready and prepared to go prior to the onset of enhancement.

Ground surface weather conditions naturally play little or no part on the received signal levels. It is what is going on above 30,000 feet that is determining the enhancement. Simply put, it is believed that, given stable conditions "upstairs" (viz winds are minimal and temperatures consistent) signals are higher and remain present for longer periods. Unstable conditions and jet stream effects diminish both these parameters. A simple check of the weather map gives some guidance to what may be expected. Close isobar lines between the cities in question invariably relate to lower enhanced conditions (time and level). It has been found that winter seems to provide better enhancement (on average) than summer, and evenings better than day and mornings. This is a subjective assumption related only to our operations over the past few years which may have to be qualified through a more scientific approach. It does however support the theories although it is a somewhat "chicken and egg" situation. The baseline is however from a practical sense the period of enhancement (for 144 MHz) can vary (for a single aircraft) from 2-7 minutes and is present for better than 95 percent of each aircraft pass.

I mentioned "for a single aircraft" in the previous paragraph and on this aspect we find additional benefits from our "bunched domestic time table" which, although most inconvenient to most travellers is helpful to us as amateurs. As you are aware our domestic airlines on the Sydney-Melbourne route run almost parallel services. In practice this provides two flights separated by about 8-15 minutes. This aspect does provide on many occasions continuous enhancement spanning 15 minutes or so. Throw in an International flight or two in a similar time bracket and you can see we have a propagation medium of practical proportions. Thus aircraft enhancement is not quite the "flash" propagation you may first believe.

The extra flights have a side effect. Now we get QSB! This results from multipath effects between the medium or body of the aircraft in transit. It varies from extremely rapid (making copy difficult) to extremely slow, and seemingly occurs when one aircraft is leaving the mid path area utilised for the enhancement path. It also relates to the speed and direction of the aircraft involved.

The flight path of the aircraft is of prime importance. Coincidentally, my location favours the Sydney-Melbourne route where I have a small incident angle. This is not a limitation to others off route. It has been proven that stations from Geelong to Frankston to Lilydale are all able to use this propagation medium. How far either side of the aircraft track this is possible (given the height of the aircraft and stations separation) has, as yet, to be accurately defined. Activity has not been great but hopefully others reading this article may become sufficiently interested to participate. What is known however, is that David VK3AUU in Drouin South, has worked Gordon VK2ZAB in Sydney. The enhanced period is short, but present at about 80 kms from the aircraft track.

What aircraft routes are useful? Well that's dependent upon the respective locations. In the Melbourne-Canberra-Sydney path, only south bound (out of Sydney) flights are practical. North bound flights (out of Melbourne) fly too far west to provide us with the direct mid path enhancement. Canberra flights are of course too low at the point enhancement.

The Sydney-Melbourne flights fly at altitudes of 31, 33, 35 thousand feet and in addition to height separation may be separated laterally. It is the most easterly path which suits us more. This has become more evident from our 432 MHz experiments to be discussed later in this article.

Obviously many factors come into play but armed with an aircraft route map, time table or VHF aircraft receiver, a hand calculator combined with a couple of suitably equipped stations you could really make a mess of the Ross Hull Contest!!

Aircraft size and type have a bearing on the received signal levels. From our observations and by use of the information given when the aircraft report their positions, we have been able to know just what we are "working off"! Naturally as would be expected the 747s and DC10s provide a higher level of enhancement. 737, 727 and aircraft of this type also provide excellent enhancement. What is somewhat interesting is that the smaller aircraft F28s etc (if flying high enough) provide similar levels. Don't get tricked on the smaller aircraft, they fly slower and naturally your predicted times will be different. Thus pure or turbo prop aircraft provide similar degrees of enhancement.

In November 1984 I dismantled my 144 MHz EME array and decided to put all my effort into 432 MHz. If you read Eric's VHF/UHF notes in this magazine you will be aware of results. Currently I run 16 bays of 16 element ATN yagis which provide just over 26dBd of antenna gain. Under terrestrial working I run 375 watts output (SSB) and the receiving system approaches 45 degrees K. With this background information the aircraft enhancement effects on this band will now be discussed.

Firstly, yes it does exist! Moreover it seems that the peak signal levels may be greater than 144 MHz, although insufficient data to confirm or deny this aspect is, as yet, to be determined.

Currently Gordon VK2ZAB is only running 10 watts to four Yagis and without a low noise preamplifier. Nevertheless we have had many two-way contacts. (The first Melbourne-Sydney 432 MHz.) Signals from me have peaked over S9 and Gordon himself has reached S9.

What we do find difficult between the two bands is the period available for communication and the signal differences between relative sites. In the first case it appears that only one half to two thirds of the enhancement period exists on 432 MHz. Secondly, the transit time of signals appearing (cross town in Canberra) is quite dramatic. Signals can be S9 at one location and inaudible a few miles distant.

I hasten to add that it is early days yet and when stations participating in our experiments improve their systems commensurate to 144 MHz, more definitive conclusions may be resolved.

Naturally as I employ a EME station capability of not too modest standards, allowances must be made in this regard. Advantages of lower sky noise and a greater realised receiver sensitivity offset or actually surpass that of 2 metres, but to discuss this and associated aspects is beyond the intent of this article. In theory my scatter signal in Sydney should surpass (by almost 6dB), that of my previous 2 metre signal, however currently the Sydney guys have as yet to reach this point. (Gordon VK2ZAB is working on it!!) Canberra stations, and in particular Ian VK1BG can copy me on scatter (CW) for greater than 90 percent of the time as evidenced from retransmissions on 80 metres. It is most useful for Ian to be able to copy (on SSB via forward scatter) for 75 percent of the time to be able to wait until signals peak (from enhancement) to S3, before responding.

I strongly believe that aircraft enhancement will support 1296 MHz and wonder just who will be the first to bridge the gap between Sydney and Melbourne on that band. Melbourne-Canberra should be a breeze!

To summarise, what can be expected? Firstly on two metres equipment wise. A well equipped station would, I consider, consist of say a single ATN 13LB type antenna (13.5dBd) fed with half inch heliax or Belden 9913 and 100 transmitter watts output power. Receiver wise a preamplifier (preferably masthead mounted) with better than 1 dB NF (BF981 or better). Such a station, if located in Melbourne, will work a similar equipped station in Sydney and expect to hear on average signals between S2-S5. On occasions short periods of up to S9 will be achieved.

On the Melbourne-Canberra path signals will "blow your head off" at times and on average be better than S7. Accordingly you may relate this to lower powers and antenna gain. It is quite easy to work this path (Canberra) with 10 watts and a modest antenna.

Don't worry about elevating the array! Signal received angles are right on the horizon due to distances involved, and secondly beam in the direct straight line path.

Some other interesting effects that have come to our notice during our scheds has been the incidence of backscatter signals off the reflection medium. When enhancement is very strong Ian VK1BG receives backscattered signals from Gordon VK2ZAB. Normally Gordon is inaudible when beaming towards me (at VK1BGs QTH) and only on the very strongest of such enhancement (towards me) are signals of this nature heard. Conversely, Gordon can hear VK1BUC, when he is beaming my way.

Multi-propagation modes in association with aircraft enhancement have been noted. Gordon VK2ZAB runs schedules northwards from Sydney on weekends. Many VK4s in Brisbane and Bill VK4LC (Mt Tamborine) are worked. I try to monitor such schedules and relate the meteor "ping" rate from week to week. Generally speaking the VK4s always provide from 5-15 (less than 1 second) pings for each 5 minute period. When meteor showers are present this increases dramatically with some classic pings exceeding 15 seconds. It has come to my notice that on several occasions I have heard Bill VK4LC with a steady signal for periods of up to one and a half minutes. Not sporadic E nor a "beaut" meteor ping! My only explanation would be that of aircraft enhancement plus tropospheric enhancement. (The distance far exceeds that for an aircraft flying at normal heights!! or maybe we have discovered a very high flying aircraft??!!!)

Finally to conclude, mention must be made of operating techniques. This is not the medium to ragchew although those suitably equipped can make a fair fist of it! Thus, it requires short, precise overs if you want to succeed and more importantly for others waiting to participate. Nothing worse than someone hogging the channel and talking through an enhancement period. Treat your operating like working the RD contest. Generally speaking if you are new at the procedure, listen for a couple of weekends and chat afterwards with those involved. Note the times you hear and whom you hear. This can be related to others and especially to your own capability. For example: a Melbourne station hearing Gordon VK2ZAB on two metres and getting him at S2 should realise he is running 400 watts and it is most likely that your 50 watts would not be heard. (This may not be quite true as most "big mouths" have associated "excellent ears" and may make up for your deficiency.) Moreover nothing is worse than stations at both ends of the circuit chatting on the scheduled frequency complaining nothing is happening.

Many has been the time when I have listened to Sydney stations on 432 MHz chatting during the scheduled period, and Gordon reports the same of Melbourne stations on 144 MHz. What is required are very short transmitting sequences and unnecessary chatter. This aspect would be beneficial on the SSB calling frequency of 144.1 and 432.1 MHz!!! For this reason Gordon and I chose 144.2 and 432.2 MHz. At one stage we were forced to work split to avoid the smart "Alecs" but this is the last thing we all would wish.

Currently these are the operating times and frequencies:

144.200 MHz: Gordon VK2ZAB "co-ordinates" the Sydney end beaming Melbourne from 0803-0900 EST (2230-2300 UTC) each Saturday and Sunday morning. He calls for the first 30 seconds of each minute and listens the last 30 seconds when things are quiet.

432.200 MHz: I (VK3UM) "co-ordinate" the Melbourne end beaming Sydney during the same period above. I call and listen alternatively each 10 seconds and monitor 3.690 MHz prior, during and after the scheduled period. If 80 metres is poor, we utilise 7.293 MHz.

Just why did we pick this particular time? Well it was convenient but we know that current flights provide at least two domestic services and generally an International flight during this period. Fog at either airport and resultant closures can cause consternation at times!

I emphasise everybody is most welcome to join and would respectively suggest if the group gets too large (as often it does) to pair off to another frequency.

There you have it: "aircraft enhancement" as we have coined the phrase and hopefully this article will inspire others to give it a try and for those scientists out there to come up with a concrete explanation of the "mechanics".

Special acknowledgements include Ian VK1BG, Ralph VK1RK, Eddy VK1VP, Les VK1BUC, Col VK1AU, Glen VK1GL, Peter VK1ZQS, Gordon VK2ZAB, Brian VK2QP, Ron VK2DVZ, Dick VK2BDN, Trevor VK3KEG, Les VK3ZBJ, Lionel VK3NM and David VK3AUU. Apologies to any that have been inadvertently missed.

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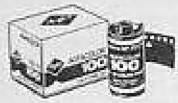
JUNE'S BEST PHOTOGRAPH



The judges at Agfa-Gevaert selected the photographs on page 21 of the June magazine. Next month the winner of the Agfa prize will be announced.