

## Tunnels in the sky?

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Over the last 40 years I've noted what seems to be an anomaly. When the HF bands<sup>1</sup> are open there seem to be missing stations. So where are the missing HF stations?

### Observations

In general non-contest operations when the band is open to a specific DX location (e.g. Adelaide, South Australia to the UK) only one or two stations from that DX area can be heard. The same phenomenon has been noted in contests; when the band is actually open to a DX area only one or two stations from that area could be heard. I've always put that down to the fact that there was a lack of activity at the other end. However, in the October 2010 SSB contest the 20 M band was open to Europe from Singapore (my location) at about 1430Z the DXCluster showed DX spots announcing the activities by a number of stations in England, and a couple of stations in Ireland, yet when I tuned to those frequencies (my software can tune to the DX frequency spot automatically), none of the stations except for EI2CN could be copied. Why was EI2CN the only station that could be heard and contacted for 15 minutes or so? He was 59, so where were the weaker stations? Why couldn't the other UK stations that were being spotted on the DXCluster at that time be heard?

In both Australia and Singapore, there are few local stations<sup>2</sup>. If you look at great circle plot of the earth centred in turn on Adelaide, South Australia, London, Washington DC and Singapore you will notice that the radio amateur population is such that when the bands are open to short skip, there are many locals to work. In Adelaide and Singapore that is not true. There are so few stations that there is often nobody to contact unless the band is open to DX. For example, operating from Adelaide over the first decade in this century, the VK6RBP and ZL6B 20 Meter beacons could be heard at many dB over S9 with one other station on the entire band (CW or SSB). Sometimes, calling CQ automatically for 30 minutes at a time resulted in no contacts. The local noise level was often as low as S1. In fact, when the band was open under poor conditions DX stations at S3 or so who were not able to hear me because of their local QRM or QRN levels could be heard<sup>3</sup>. When conditions were good, different stations at various signal strengths could be heard.

Short wave radio propagation theory purports that the ionosphere reflects like a mirror. Different frequencies get reflected different distances at different times of day. There are times when there is no propagation between two locations and there are times when there is propagation. When there is propagation, the ionosphere acting as a mirror should reflect all the signals between the locations. However, when the band is actually open, not when predicted to be open, the stations that should be audible, since my receiver and antenna let me hear weak stations, are not being heard.

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<sup>1</sup> 40M to 10M.

<sup>2</sup> In Europe and the US the problem is finding a clear frequency. In other parts of the world, the problem is reversed. The problem is finding someone to talk to.

<sup>3</sup> I know, I have tried calling them. CW gets through much of time, but SSB is a lost cause under those circumstances.

## Analysis

The following aspects of the situation were considered.

- **My receiving set up.** I've generally been lucky and have had low local noise and can hear much further than I can speak as discussed above<sup>4</sup>. I spend lot of time listening and tuning. Occasionally I have worked weak stations that showed up on a frequency for a few minutes and then faded away.
- **Good and poor conditions.** The situation has been more or less the same through the last 10 years, 2000-2007 in Adelaide and 2008-2010 in Singapore.
- **The geometry of the path.** The stations in the DX area may have had their beams edge on to Adelaide and Singapore; so yes, the signal levels would be down. However, since the local noise level is low, and I can hear weak stations, many of those stations not beaming directly at me should be heard at some weak signal level. In addition, stations not using beams ought to be audible. A typical three-element YAGI beam used by many radio amateurs on the 20M, 15M and 10M bands can have a front-to-side rejection ratio of 36 dB. If all the missing stations were beaming edge on, that would put their received signals 6 S units down as shown in Table 1. If one station booming in at S9+ can be heard, stations down to S1 and 2 should be audible and the other stations from that area should be heard. Operating during a contest from a location in Europe or North America, hearing stations at those low levels is often impossible<sup>5</sup>. However, in Singapore and Adelaide hearing stations at S1 is no problem. Copying SSB voice at S2 is a breeze<sup>6</sup>.

Table 1 Power to signal strength relationships

dB	Change	S units	Received reports
0 dB		Reference	1024 Watts = S9
3 dB	x2		
6 dB	x4	-1	256 Watts = S8
9 dB	x8		
10dB	x10		
12dB	x16	-2	64 Watts = S7
15dB	x32		
18dB	x 64	-3	16 Watts = S6
20dB	x 100		
21dB	x 128		
24dB	x 256	-4	4 Watts = S5
30dB		-5	1 Watt = S4
36dB		-6	0.25Watt = S3

- **The relative signal levels.** I'm running low power; they may be running various power levels. But I'm not discussing them hearing me; I'm discussing my not hearing them. My receiver ought to have heard them as shown in Table 1 and discussed above.

<sup>4</sup> And very frustrating it can be.

<sup>55</sup> This difference between the signal levels produced by high-power transmitting stations being called by low-power DX stations is one reason for the many 'lack of ears' reports on the DX spots.

<sup>6</sup> Don't be jealous, it's frustrating because they can't hear you.

- **The frequency.** It seems to happen on 10M through 40M. I haven't seriously operated on 80M and 160M so have no data.
- **The way people operate.** The serious contester in Singapore and Australia who spends most of the time calling CQ would probably not notice this phenomenon; he'd respond to the strongest stations and assume that the missing stations were either not there or too weak for him to hear them. Other stations who tune for contacts might not notice the same phenomena if they do not have Internet DXCluster information.
- **Why the issue has not been mentioned before.** Digging through memory I do seem to have noticed the same thing operating from Silver Spring, MD (W3), England and Jerusalem (4X) over the years. I'd tune the bands and hear only a few stations from one area<sup>7</sup>. But from 1970 to 1990 I had no way to know if there were more stations active than those I could hear. By the early 1990s' there were PacketClusters and then Internet DXClusters. And there was software that could tune the transceiver to the DX spot frequency. Operating from Silver Spring, MD, stations that were spotted by other East Coast stations were generally receivable. This just told me that I could hear the same stations that others were hearing. At that time, we had no way of knowing if any DX stations were transmitting and not being heard.

Serendipity struck. In my professional life I teach systems engineering. I needed to teach students how to create software models, test the models and put them together to make a simulation. For that I needed a case study to use as an example where I could take the students through the whole system development lifecycle from conception to operation. I dug out a software simulation of the American Radio Relay League (ARRL) 1977 Sweepstakes contest that I had written 30 years ago (Kasser, 1984). The software contained five models that determined if a contact could be made with a specific ARRL Section at specific times of day; propagation of HF signals being but one of the models. Creating the lecture reminded me of these observations. And, by some coincidence there was an article on HF propagation in the December 2010 issue of QST (Nichols, 2010) which cited an earlier article (QST, 1940) which summarized the Bureau of Standards Letter Circular-575, an up-to-date [for 1940] summary of known ionosphere effects. I dug out the 1940 article to see if it could shed any light on my observations<sup>8</sup>. The following issues appeared to be pertinent -

1. The ionosphere, located between about 50 and 500 kilometres above the surface of the Earth, can reflect radio signals transmitted from one area on the surface of the earth back to another area on the surface at a distant location.
2. There may be a considerable number of layers in the ionosphere at any one time but they can be grouped together.
3. Scattered reflections. *"An irregular type of reflection from the ionosphere occurs at all seasons and is prevalent both day and night. These reflections are most noticeable within the skip zone, or at frequencies higher than those nominally receivable from the regular layers. Like sporadic E, they occur at frequencies which may exceed the F<sub>2</sub> critical frequencies, but are unlike sporadic E in that they are complex and jumpy causing signal distortion; they occur and disappear fitfully, and are almost useless for communications purposes. Some types are of very weak intensity. The scattered reflections are characterized by very great virtual*

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<sup>7</sup> Within a single skip zone and DX.

<sup>8</sup> I teach my students that if they can, they should always check the original source.

*heights. Usually somewhere from 400 to 1500 kilometres. Their occurrence was thought for a time to indicate the existence of another layer above the F<sub>2</sub> layer which might be called the G layer. It is now, however, thought that they are of several types, and that some of them are due to complex reflections from small, ephemeral, scattered patches or "clouds" of ionization in or between the normal ionosphere layers, and thence to one or more layers and ground by single or multiple reflection."* This looked like a description of meteor scatter to me.

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In 1940 the G layer theory was being replaced by a complex reflection theory. Today we describe these reflections as meteor scatter. The history of science can be considered as theories being replaced by subsequent theories once facts that don't fit the earlier theories are observed and accepted (Kuhn, 1970). I wondered if there was a way to modify the mirror reflection theory in some manner to explain the observations.<sup>9</sup> Yes there was. It has been noted that VHF and UHF signals can be propagated for long distances via ducts that form between layers at different altitudes. The size and position of the ducts change and sometimes can be very localized such that if stations are only a few miles apart or even a few hundred meters apart, one can get signals into the duct and the other cannot. A hypothesis that seems to explain these observations of missing stations is that HF propagation through the ionosphere is via similar ducts or tunnels in the sky formed between the different sub-layers of a layer in the ionosphere rather than via a wide area mirror reflection. The ducts move around or change shape which is why propagation conditions vary<sup>10</sup>. This article is not suggesting that the mechanism that forms a duct in the troposphere is the same as the mechanism that forms the duct in the ionosphere; it is just postulating the existence of ducts in the ionosphere through which radio waves get propagated.

I also remember reading about some locations being better for working DX than others but can't locate the articles at this time. The ducting theory would postulate that some locations can't access ducts that form in certain situations.

Back in Detroit in 1972, I was operating with a mobile whip from my balcony on the second floor (Kasser, 1974). By raising and lowering the end of the whip I could bring up the signal strength on some DX stations on 10M and 15M to the point where I could beat high powered locals in a DX pile up and come away with the contact. At the time the assumption was that changing the angle of elevation and optimising it for the particular path. Now I wonder if I was putting a better signal into an ionosphere duct.

## Testing time

The scientific method requires that others be able to replicate the observations. So,

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<sup>9</sup> This is the scientific method. Make some observations, state a hypothesis, and look for data to support or refute the hypothesis. If experimental data refutes the hypothesis, think again and make a new hypothesis. In layman's terms – trial and error.

<sup>10</sup> This situation can be seen in instances of sporadic E on 10M and 6M. I remember watching 50MHz Band 1 TV from Jerusalem on summer Sundays in 1981 and 1982 with a simple fixed dipole. I was able to see stations from Eastern Europe slowly being replaced by others further westwards. The pattern was repeatable. In addition, late in the evening, after the local TV station had signed off, I was often able to view the Harare TV station via transequatorial propagation mostly with multipath "ghosts" that made the picture unviewable, but apparently did not affect the FM audio.

1. Has anybody made similar observations?
2. Has anybody noted that they cannot copy stations being reported by locals (to them) on the PacketCluster or the DXCluster after making allowances for the differences between the receiving set ups?
3. Would more stations from Australia, New Zealand and other locations where the band occupancy is sparse start to spot DX and whether they can copy DX being reported by their locals<sup>11</sup>.

In these early years of the 21<sup>st</sup> century amateur radio has real-time links to various parts of the world via the Internet. As well as the DXClusters some radio amateurs have connected their stations to the Internet. This facility provides functionality that was previously unavailable. For example in the closing hours of the 2001 ARRL Sweepstakes I was at my desk in Adelaide where it was Monday morning. I remembered about, and linked to the W4MQ station web site in Northern Virginia and made 15 contacts in the contest as W4/G3ZCZ (announcing there were via W4MQ remote)<sup>12</sup>. I tried the link a few times later from home but was never able to work myself. With the current advent of DXClusters, Software Defined Radios and other web-interfaced radios it should be possible to set up some experiments to determine:

- (a) if the observations are repeatable under controlled conditions, and
- (b) collect data that might give us some idea of the size, shape and nature of the ducts.

It was observations by radio amateurs that opened up the High Frequency bands for communications in the early days of the 20<sup>th</sup> century. If something hasn't been overlooked, then perhaps this study will show that we, radio amateurs, can still contribute to the theory of radio propagation in the 21<sup>st</sup> century. We have at least two major advantages over the professionals – (1) there are a lot more of us, and (2) we don't need to wait for research grants/funding to conceive and carry out experiments.

## Summary

Over the years I have noticed that when the HF bands were open all the stations that should have been operating from the DX locations were not being heard. The assumption was that this was due to a lack of activity in the DX location. However, recently, through the use of the DXCluster technology DX spots showing that stations that could not be heard were active from a DX area when at least one station from that area could be heard. According to the ionosphere mirror reflection theory they should have been audible, even if weakly. As a result this article has postulated that the ionosphere mirror theory needs to be modified to explain the observations of missing stations. I'm requesting that if other stations have made similar observations, they report their observations. The hypothesis is that radio waves in the ionosphere are propagated via ducts or tunnels in the sky in a similar manner to the propagation of UHF and VHF in the troposphere.

## References

Kasser, J. E., "*Apartment Dweller's Antenna System*", 73, Vol. (1974).

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<sup>11</sup> Free software can be provided.

<sup>12</sup> I claim the first contest operation via an Internet remote site. The time delays made the operation interesting. Earlier experience operating as W3/G3ZCZ, Silver Spring, MD allowed me to anticipate the exchanges and most of the contacts did not realize they were communicating with a virtual station.

Kasser, J. E., *Software for Amateur Radio*, TAB Books, Inc., Blue Ridge Summit, PA, 1984.

Kuhn, T. S., *The Structure of Scientific Revolutions*, The University of Chicago Press, 1970.

Nichols, E., "Gimme an X, Gimme an O, What's that Spell? - Radio", QST, Vol. 94 (2010), no. 12, 33-37.

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