Some Thoughts on Vertical Ground Systems Over Saltwater

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Over the years I've been asked for advice on verticals placed directly over seawater. Unfortunately the only case I've much experience with is a sailboat floating in the ocean but that's rarely what the questions I receive are about. Most of the time it's for a DXpedition with a waterfront QTH with or without a pier or dock and perhaps with a shallow reef which alternately floods and dries. I have to admit I haven't given a lot of thought to those situations so you should view my comments with caution.

At first blush, putting a vertical directly over seawater would seem to be ideal but there are practical details which sometimes spoil the fun. There are many issues but efficiency and far-field pattern are near the top. Besides conductor and loading coil losses, ground loss in the near-field is a major concern. Most of the ground loss is concentrated within 1/2-wave of the base of the vertical, so from an efficiency point of view you don't have to get very far out from the beach if you want to put the antenna over water. The far-field radiation pattern on the other hand is determined by the ground characteristics out to many wavelengths which you can't do anything about except look for a better site. Going further out on the pier won't help much with the far field unless of course you have access to a really long pier like the old Berkeley ferry pier on the east side of San Francisco bay. When constructed the pier was 3.5 miles long. The far end of the pier would have been a great QTH!

However we can work on the ground system to improve efficiency. We might use a conductor or conductors inserted directly into the water or some form of elevated radial system. I received a query from Bill, N7OU, concerning the installation a multi-band verticals directly over saltwater without a pier or dock. The verticals required some form of ground system. He and Bob, W7YAQ, were headed out for T3Ø, Tarawa. Adjacent to the operating site there's a large shallow lagoon and the question was "can we just stick the verticals right out in the saltwater with some simple ground system and have a super signal?"

When an AC current flows in a conductor the current tends to flow only near the surface. The depth of penetration where the current level is reduced to 1/e or about 37% of the surface amplitude is called the "skin depth". Almost all the current flows within two skin depths of the surface. Saltwater is a pretty fair conductor so the skin depth isn't very large at HF, as shown in Figure 1. On 40m for example, the skin depth is only about 3.3".

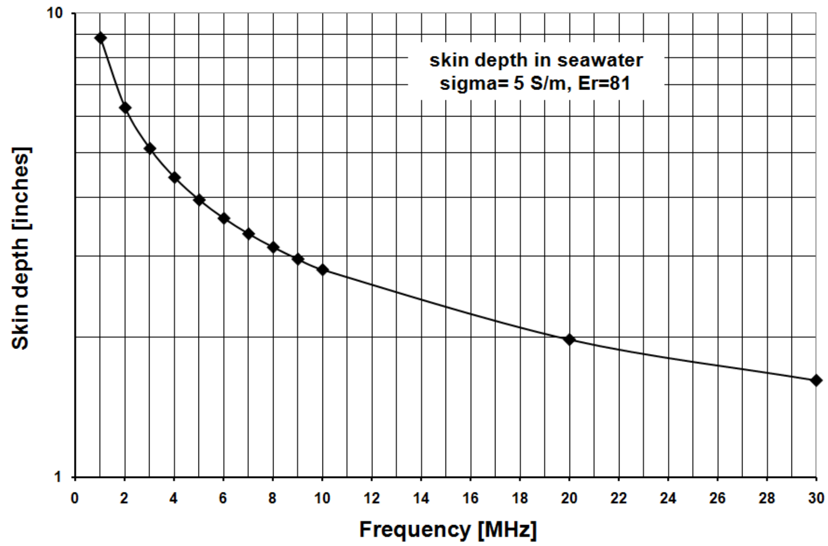

Figure 1, Skin depth in saltwater at HF in inches.

Figure 2 shows how this relates to a vertical which has its base connected to a pipe immersed in seawater.

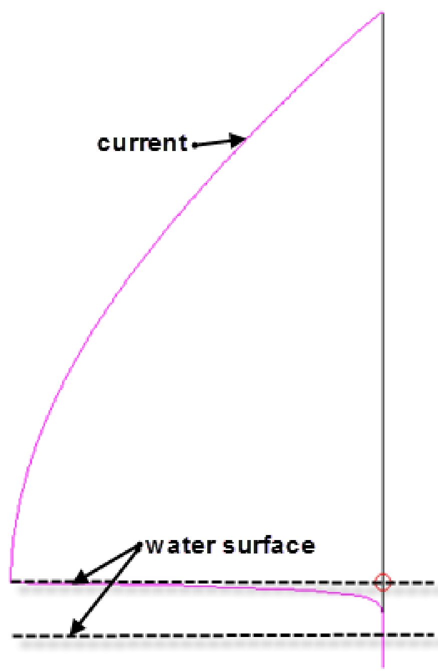

Figure 2, 40m λ/4 vertical over seawater supported with a conducting post immersed in the water. f= 7.2 MHz and h= 33.1'.

As you can see the current on the "ground connection" drops very quickly, becoming essentially zero by 10-12" down. The ground current for the vertical is restricted to a thin layer near the water surface. Two water surfaces are shown: the upper surface represents high tide and the lower one low tide (note, I did not show current distribution for the second case to make the figure less cluttered). Over the world the local tidal range varies from a foot or so to fifty feet or more (ala Bay of Fundy). The point is that with the arrangement shown in Figure 2 the effective length of the antenna will change, perhaps drastically, with the tide or a even a passing wave. This of course grossly detunes the vertical. Bill pointed out that there is another solution ala VK9GMW: use an automatic antenna tuner at the feedpoint to compensate for changes in feedpoint impedance as the tide varies (**vk9gmw.com/documents/VK9GMW ANTENNA.pdf**).

Plan A is not too promising. However, there is an alternative that would work if by chance you have a floating dock or even just a float substantial enough to support the vertical which will rise and fall with the tide. Then the arrangement in Figure 2 will work great, even for a multi-band trap vertical. The length of conductor into the seawater needs to be only about 12" or so but should have a diameter of 12-24" to provide a low-resistance ground. The loop could be thin sheet metal or screen. Of course most of the time this is just a temporary arrangement. For longer term use you'll have to take into consideration metal erosion due to electrolysis and the growth of marine organisms. The only material that I'm aware of for long term use is one of the copper-nickel alloys but even they have to be cleaned regularly.

For single-band operation a number of DXpeditions have placed their verticals out on a reef that floods with only two opposing $\lambda/4$ elevated radials. Directly over seawater even as few as two radials can be efficient. There is a little pattern distortion with only two radials but it's small. There will be some change in tuning as the water level shifts which can be minimized by keeping the radials well above the water surface even at high tide, say several feet. Putting aside the issues of cables in the water, corrosion of connections, anchoring guys, etc, this approach can work as Dean Straw, N6BV, has shown (*Antenna Compendium Vol. 6*, page 216). But for a multi-band vertical the elevated radial approach over water becomes complicated and may not be practical. One caveat regarding elevated radials attached along a pier or a floating dock. Some time back Robye Lahlum, W1MK, told me about experiments he had run where a vertical was mounted on a treated wooden post. It turns out that the salts used in wood treatment are conductive and the losses can be very high, to the point heating the wood to ignition! Docks and piers generally use treated wood so you'll have to be careful to keep the vertical and any radials well away from the wood. Don't just staple the radials to the dock!

Another option, of which George, W2VJN, reminded me, is to use one of the multi-band verticals like a Cushcraft R7000 which are designed to be operated without any additional ground system. In my ground system experiments described in QEX (May/Jun 2009, pp. 41) I ran a few tests on that antenna, with and without a ground system. The presence of 60 λ/4 radials at the base of the antenna made only 0.1 dB difference in the signal strength.

It should be kept in mind that as long as you use a substantial number of radials (30 or more, 1/4-wave long or more) the ground losses will be pretty low. In practice it may be more convenient to place the vertical on the beach with a radial system spread around it. The ground system which Bill and Bob planned use was simply thirty-five 10m radials connected to a base plate. The tests reported in *QEX* (Nov/Dec 2009, pp. 19, available at: **www.antennasbyn6lf.com**) showed that thirty-two 33' radials worked very well from 40 through 10m whether on the ground or elevated. With this many radials the wire size can be #18 or even smaller. Stranded, insulated hookup wire works just fine and is easy to work with. If the wires are attached to the plate in advance and simply coiled up for transport, laying out the ground system on the beach should only take a few minutes for each antenna. I had a ground system like this made up for the tests reported in QEX which I had to pick up and lay down many times during the experiments. I found that very easy to do. Of course that was for 40-10m. If you want a ground system for 160m then a mono-band two-wire elevated radial system over the water might be more practical.