A Sarantel Antenna Primer

Executive Summary

The antenna is arguably one of the simplest structures in the communications chain, but one of the most difficult elements to design and control. Conventional antennas are really just resonators, using the entire handset as the antenna structure to increase the apparent size and efficiency of the antenna system. Unfortunately, this approach leads to deleterious effects on the communications chain when human interaction with the antenna is taken into consideration. The efficiency of a conventional antenna drops dramatically when the device is actually put in service by the user. Sarantel takes a different approach to antenna design. The PowerHelix® filtering antenna is isolated both from the noisy electronics in the handset and from interaction with the user, creating a highly stable, predictable frequency response and efficiency. Further, the PowerHelix can have a positive impact on the efficiency of the entire communications chain by increasing the signal-noise ratio in the radio through integral filtering characteristics and in-band noise rejection. This article will explore fundamental properties of conventional and PowerHelix antennas, showing the benefits to be derived from the PowerHelix technology approach.

Introduction

In the drive to improve every aspect of handset design and performance whilst keeping the handset small and appealing to consumers, OEMs and ODMs have hit rather hard some of the physical realities governing the very first and arguably simplest element in the communications chain: the antenna. This article reviews the fundamental properties of conventional antennas as they pertain to handset design and performance, and explores Sarantel's approach to antenna design: the PowerHelix™ filtering antenna.

In its simplest form, the antenna is a bit of wire through which a current passes, causing it to resonate at a frequency determined by its length and with an efficiency and bandwidth determined by its size. With antennas, size matters, and bigger is better. All things equal:

$$\frac{\text{Gain * Bandwidth}}{\text{Volume}} = \text{Constant}$$

In other words, the smaller the antenna the lower its gain and/or bandwidth. This is mitigated somewhat by the fact that the antenna isn't actually the bit one sees atop the handset. The conventional "single-ended" antenna used in the vast majority of handsets uses a ground plane to balance out the currents fed to the antenna, effectively increasing its size. In fact, one could say that the entire handset IS the antenna. This would seem to solve the size versus efficiency problem nicely for small handsets, but it doesn't.

The Human Factor

Into the equation we must put the human factor. People have a dramatic impact on the efficiency and effective resonant frequency of an antenna that can be very easily be demonstrated by common experience (for those of us old enough to remember!). Everyone will have experienced the frustration of tuning in a television station by adjusting the television antenna, only to find that the station became "snowy" immediately upon moving hands away from the antenna. The same effect happens with all antennas, and what it is demonstrating is the human interaction with the near-field of the antenna.

There are two fields associated with antennas: the near-field and the far-field. The far-field can best be visualized as the radiation pattern of the antenna, or the field that defines its gain and efficiency. It is this field that handset designers are seeking to maximize for peak handset performance. The near-field is a resonant pool of energy stored around the antenna in the air or other dielectric medium near the antenna. This field is associated with the poorly labeled "handset radiation" in popular media discussions of handset SAR.

The near-field is arguably the more important of the two fields because without it there could be no far-field. A loss of near-field energy leads directly to a loss of far-field efficiency. This is where the human comes in. In a free space system, near-field energy is stored in the air surrounding the antenna. This energy will flow to any medium better able to conduct it than the air, and as it turns out, human beings are mostly made up of salty water about 40 times better at storing and absorbing near-field energy than air. Since by rule of thumb the near-field extends approximately 3 wavelengths from the antenna (≈45 cm at 3G wireless frequencies), any part of the human entering that field, e.g., by grasping the handset, will begin to drain the near-field of energy and adversely affect the antenna's efficiency.

A second effect of the human interaction with the antenna is a change in the antenna's apparent size. Remember that an antenna's resonant frequency is determined by its length. The human interaction with the fields around the antenna make the antenna seem longer than it really is, and a longer antenna resonates at a lower frequency. Thus the "snow" when your hands are removed from the TV. Figure 1 shows both of these principles in action in a conventional GPS antenna. The graph on the left shows the far-field pattern of the GPS antenna in both free space and with a hand near the antenna. Note that the pattern (bigger is better) has collapsed when the hand is present. Likewise, the graph on the right shows the resonant frequency of the same antenna by showing its point of least return loss (deepest point in the trough). With the hand close to the antenna, the frequency shifts down because the antenna appears longer than in free space. Note that the significant shift in frequency occurs when the hand is in the 3-wavelength near-field region, which for GPS begins at approximately 57 cm.

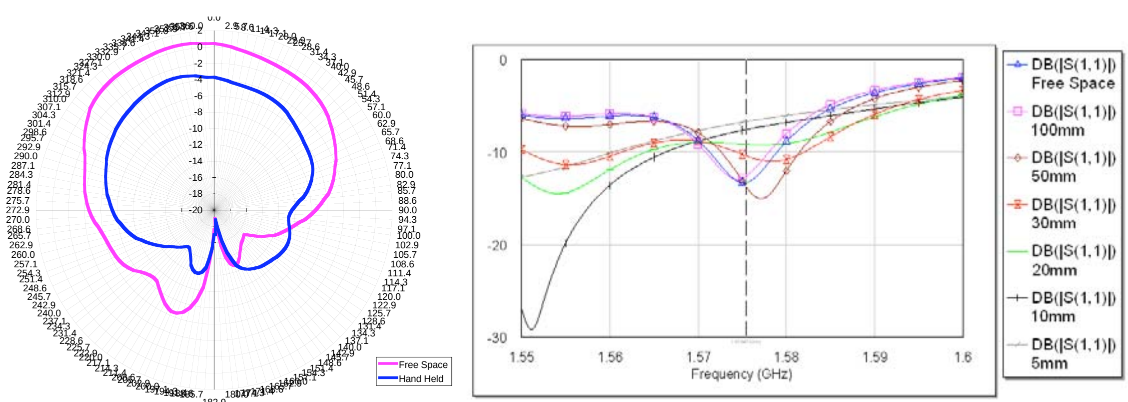

Figure 1. Radiation Pattern and Return Loss Chart of GPS Patch Antenna in Free Space and with Hand-loading

An interesting implication of this frequency shifting due to the position of the user's body with respect to the antenna is that the designer of the handset must predict the loading effect, and design the antenna with a best efforts view of how the handset will be used, i.e., held in the hand while viewing a video stream or held next to the head while talking. A poor design will result in the antenna being optimized for the wrong application.

There are many other measures for the effects that the dielectric tissues of the human body have on antenna efficiency and performance. Suffice it to say the problem is real, and is magnified as handsets get smaller, forcing designers to compromise efficiency and bandwidth. From the consumer's perspective, the greater the performance demands on the radio, the greater the likelihood of dropped calls and low data throughput rates.

The PowerHelix Filtering Antenna

Sarantel has taken a novel approach to the efficiency versus size and human interaction problems through its PowerHelix filtering antenna technology. Rather than take the conventional path of trying to make the antenna seem larger and more efficient by resonating the platform to which the antenna is attached, the PowerHelix approach isolates the antenna from both the handset and the user, physically and electrically, through a combination of structure and materials. This approach leads to several benefits above and beyond frequency and performance stability.

Sarantel employs a twisted loop structure for its antennas, appearing much like a double helix. To that structure is added a balun, a construct that constrains the currents fed to the antenna within the loop structure of the antenna itself. This creates current balance, so no ground plane is required to absorb currents from the antenna, effectively isolating the antenna from the handset. Finally, the antenna is plated onto a ceramic cylinder with a dielectric constant approximately equal to that of human tissue. Figure 2 shows the main elements of a PowerHelix antenna.

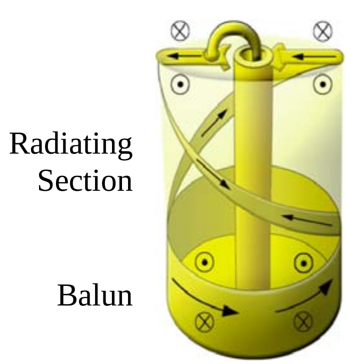

Figure 2. PowerHelix Antenna Structure

The chief aim of the structure and materials of the PowerHelix antenna is to create an efficient antenna system that doesn't suffer from the loading effects described. This is accomplished in three ways. First, as mentioned the antenna is balanced. This means that all currents provided the antenna remain within the radiating section of the antenna, with the balun acting as a "choke" to prevent current exchange with the radio by any means other than the feed system. This isolation is very important in a constantly transmitting/constantly receiving system like 3G wireless as will be discussed.

Second, by twisting the loop structure of the antenna, the magnetic fields are constrained very tightly around the antenna because the twist causes a magnetic field reversal at the midpoint of the twist (positive to negative, negative to positive). These tightly coupled magnetic fields contribute to concentrating the near-field close to the antenna, and shrinking the volume exposed to human interaction.

Third, the high dielectric substrate of the antenna acts like a capacitor, drawing the near-field energies into the antenna. To be sure, the structure does have a near-field, i.e., the near-field doesn't completely collapse otherwise the antenna would not be a radiating structure at all. However, depending on the relative permittivity of the material used, the near-field shrinks to and is highly concentrated in a volume that extends less than a centimeter from the antenna. As a result, the human has to get quite close to the antenna to have any effect on its performance at all. Figure 3 shows quite a stunning example using a GeoHelix® GPS antenna for comparison. Again, the far-field radiation pattern is on the left and the return loss is on the right. Note that there is little effect on the resonant frequency of the antenna even when the hand moves within a centimeter of the antenna, and the efficiency of the antenna as observed in its pattern is virtually unchanged.

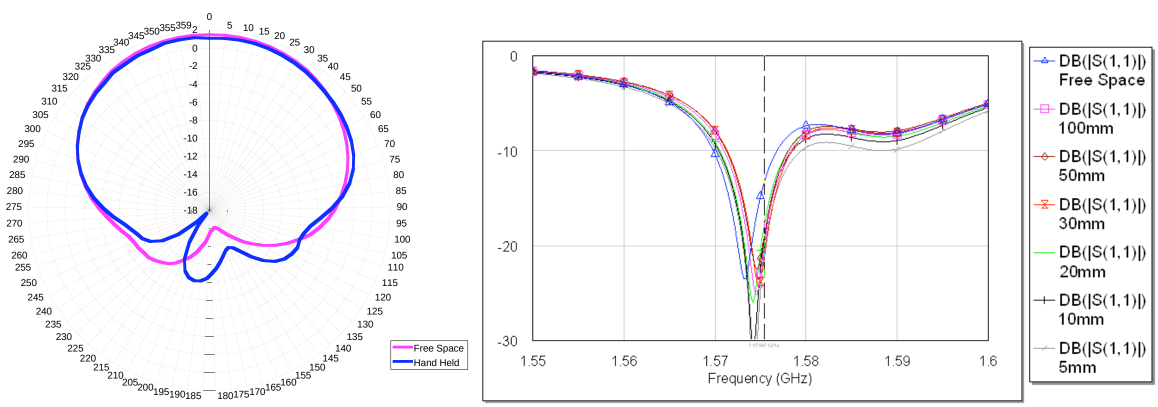

Figure 3. Radiation Pattern and Return Loss Chart of GeoHelix GPS Antenna in Free Space and with Hand-loading

Figure 3 represents quite an unusual result in the field of antennas, in that the stability of the PowerHelix antenna performance and resonating frequency can be assumed with high confidence at the beginning of the design cycle, independent of how the end device will be used. The iterative process a designer must go through with conventional antennas to adjust the size and characteristics of the antenna system as changes are made to the platform around the antenna is unnecessary with the PowerHelix antenna. Further, there are other important benefits to be derived from this structure.

Dielectric materials have the effect of shrinking the size of a structure for a given resonating frequency. The higher the dielectric constant of the material, the smaller the antenna at that frequency. For example, a 2.3GHz antenna built on a material with a relative permittivity of 40 would be roughly the same size as a pencil tip eraser. That same antenna on a material with a permittivity of 20 would be about the size of a thimble. By varying the materials on which the antenna is built, different styles of antennas can be achieved for different application aims. Figure 4 shows a PowerHelix antenna on the higher dielectric material that would resonate near the 3G wireless bands.

Figure 4. Small PowerHelix Antenna with Center Frequency ≈ 2GHz

These materials also tend to produce very narrowband response, i.e., the bandwidth over which they effectively resonate is much narrower than an open field structure. By controlling the breadth of the PowerHelix antenna's frequency response, the antenna becomes its own filter, filtering out undesired signals in adjacent frequency bands. This effect can reduce the cost of the required filtering system in the radio itself.

A very important feature for 3G wireless of the PowerHelix antenna structure mentioned earlier is its isolation from currents on the radio. One key measure of radio performance is Signal-Noise Ratio (SNR). Simply put, the SNR is the signal left in the communications link once noise from all sources is subtracted out. Obviously, there are two ways to maximize the SNR: raise the signal output and/or lower the noise input. Currents residing on the ground plane of the handset are a significant source of noise that can impair the communications link. Out-of-band noise can be filtered out through discrete filtering mechanisms in the radio. However, in-band noise is conducted by the ground plane of a conventional antenna directly into the receiver, because there is no electrical isolation between the ground plane and the antenna in a conventional antenna system. The PowerHelix antenna does not provide such a path for this in-band noise – such noise is rejected. This results in higher SNRs, all other things being equal.

Additionally, in a constantly transmitting/constantly receiving system like 3G wireless, it is important that the antenna systems for the transmitting and receiving frequencies be isolated from each other, so the transmitter doesn't impair the signal being received. With conventional antennas resonating against the entire handset, this is very difficult if not impossible to achieve because in addition to ground plane coupling there is near-field coupling (unless the handset places the transmitting antenna 45 cm away from the receiving antenna!). With the PowerHelix antenna, the transmitting and receiving antennas can be placed as close as 1 cm apart – no coupling can occur, either on the ground plane or via the near-fields.

No Free Lunch

Of course, there is no free lunch. Size does matter, and the smaller the resonating structure, the lower its gain and/or bandwidth. PowerHelix antennas typically resonate at half the frequency of conventional antennas *in free space*, but their efficiency does not change in use; conventional antennas will lose 80% or more of their efficiency in use, so on balance the PowerHelix approach yields a more efficient antenna for the application.

PowerHelix antennas are sometimes a little too narrow in their frequency response, but this can be addressed by adding a second resonating structure to the antenna (see Figure 4). This second loop causes multiple modes on the antenna, each resonating independently. By spacing the modes across the desired band, a broader bandwidth response is achieved. Figure 5 shows such an example for a 2.4GHz ISM band antenna.

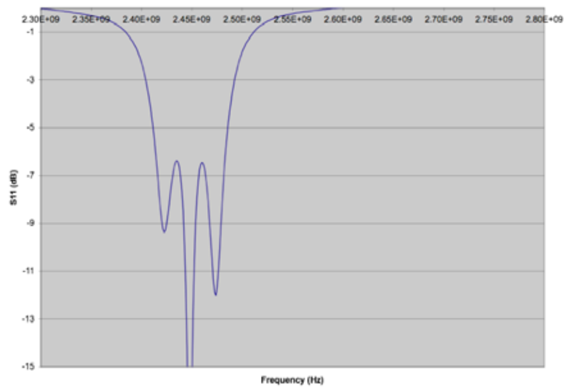

Figure 5. Multi-pole Response of Bi-filar PowerHelix Loop Antenna

Conclusion

In summary, the antenna on a wireless device can do much more than deliver signals from the air to the receiver or from the transmitter to the air. In the case of a conventional antenna, the antenna can act as a noise conductor, reducing the efficiency of the communications system. The PowerHelix antenna addresses the shortcomings of conventional antenna technology by separating the antenna from the device, allowing it to resonate independently and isolating it from noise generated by electronics within the system. Most importantly, the PowerHelix antenna isolates the antenna from the impairments that arise when the user interacts with the fields around the device, creating a stable, predictable resonating structure whose characteristics can be relied upon from the beginning of the design cycle straight through to when the user takes advantage of the advanced services made possible by 3G wireless technologies.

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