

Transmission and reception of faster than light longitudinal dielectric waves

Currently, virtually all the wireless communication devices we use are based on electromagnetic induction, which includes near field and far field communication systems as well as wireless energy transmission systems such as contact-less battery chargers. Besides electromagnetic induction, however, dielectric induction is known to exist, yet has hardly been practically applied for the transmission of energy and/or information, even though Nikola Tesla has demonstrated both the transmission of energy and the transmission of information to be feasible around 1900.

Because of the success of Marconi's radio transmission system, Tesla's dielectric induction principle has been all but forgotten, were it not for a handful of replications of Tesla's transmitters which demonstrated the validity of this principle as recently as 2001, while also demonstrating Tesla's original design can be scaled down to operate well into the several MHz range.

However, because Tesla's original system did not employ a ground / reflector plate, the earth itself acts as ground / reflector plate, which results in various problems such as that the height of the antenna with respect to the ground influences its behavior. This limits the possibility of scaling down the antenna for higher frequencies. At 10 MHz or so, with a wavelength of 30 m, it is not such a problem to use the earth as a ground plane. At 1 GHz, with a wavelength of 30 cm, the distance to the ground plate becomes really problematic, because resonance has to be established between the elevated capacitor and the ground plane in order to obtain an efficient antenna. This problem is solved by this invention.

Furthermore, Tesla's system used magnetic coupling, which either requires the application of carefully designed waveguides in order to transform from EM mode to longitudinal mode transmission or requires a tuned flat "pancake" spiral coil, whereby the primary is operated as a (short) magnetic loop (antenna). While this can be done at microwave frequencies as well, we can also use capacitive coupling between the feed and the antenna, which eliminates the need for any coils in the antenna system and allows an antenna design that can be fed with a standard un-balanced (coax) feedline.

Historical background

In 1834, Sir Charles Wheatstone measured the propagation speed of electricity along a single wire, which resulted in a calculated velocity of 288,000 miles per second (463491.1 km/s), about 1.55 times the speed of light. This is remarkable, because in 1862 Léon Foucault measured the speed of light using Wheatstone's revolving mirror idea and came within 0.6% of the currently accepted value, with essentially the same measuring method. When we assume, however, that Wheatstone actually measured a longitudinal form of electricity instead of the transverse form we are currently using, his result would be within 2% of the theoretical value of $\pi/2$ times the speed of light.

In 1861, James Clerk Maxwell published his paper "On Physical Lines of Force", wherein he theoretically derived a set of equations which accurately described the electro-magnetic field insofar as known at that time. He modelled the magnetic field using a molecular vortex model of Michael Faraday's "lines of force" in conjunction with the experimental result of Weber and Kohlrausch, who determined in 1855 that there was a quantity related to electricity and magnetism, "the ratio of the absolute electromagnetic unit of charge to the absolute electrostatic unit of charge", and determined that it should have units of velocity. In an experiment, which involved charging and discharging a Leyden jar and measuring the magnetic force from the discharge current, they found a value $3.107 \cdot 10^8$ m/s, remarkably close to the speed of light.

In 1884, Oliver Heaviside, concurrently with similar work by Josiah Willard Gibbs and Heinrich Hertz, grouped Maxwell's twenty equations together into a set of only four, via vector notation. This group of four equations was known variously as the Hertz-Heaviside equations and the Maxwell-Hertz equations, but are now universally known as Maxwell's equations. Even though it was later discovered that at least two

electromagnetic wave phenomena exist, namely the “near” and the “far” fields, while the Maxwell-Heaviside equations only predict one type of waves to exist and are therefore obviously incomplete, the Maxwell-Heaviside equations have never been revised in order to incorporate this knowledge.

In his patent No. 787,412, filed May 16, 1900, Nikola Tesla disclosed a wireless system by which he was able to transmit electric energy along the earth's surface and he established that the current of his transmitter passed over the earth's surface with a speed of 292,880 miles per second (471347.9 km/s), about 1.57 times the speed of light, within 0.1% of the theoretical value for the propagation speed of longitudinal dielectric waves. Tesla also did not agree that our present "radio" waves are transverse “Hertzian” waves, but in reality were like sound waves which would be longitudinal waves.

During the 1980s Eric Dollard (N6KPH) replicated some of Tesla's work by scaling down Tesla's Magnifying Transmitter (TMT), patent No. US1119732A, for operation in the 80 meters radio amateur band. Besides these experiments, he also measured the propagation speed of longitudinal dielectric waves along a single conductor. He demonstrated that the wave propagation velocities of transverse waves and longitudinal waves are significantly different, even when they are produced by the same signal source.

The wave velocity of transverse waves was determined by measuring the frequency for which low-power radio waves directly coupled to the end of a conductor of known length produced a resonance condition that resulted in a maximum voltage measured at the “far” (non-source) end of the conductor. Wave velocity was calculated as (resonant) frequency times wave length, which was equal to frequency times conductor length times four. The wave velocity of longitudinal waves was determined in a very similar manner; however, the radio waves were capacitively (i.e., not directly) coupled to one end of a conductor equal in length to the conductor used for the transverse wave velocity measurement. As was done for transverse waves, wave velocity was calculated as (resonant) frequency times conductor length times four.

The results of these determinations were as follows:

- transverse wave velocity = 2.44×10^8 m/s = $0.81 \times c$; and
- longitudinal wave velocity = 3.74×10^8 m/s = $1.25 \times c$.

The proportionality between these two speeds calculates to about 1.53, within 2.5% of the theoretical value of $\pi/2$.

In 2001, Prof. Dr.-Ing. Konstantin Meyl published his paper “Scalar waves: Theory and Experiments”, wherein he described his experiments with a scaled down version of the system described in Tesla's patent US787412A titled “Art of transmitting electrical energy through the natural mediums”, consisting of an elevated spherical capacitor driven by a flat “pancake” coil transformer, whereby the primary and secondaries are obviously magnetically coupled. He reported that two distinctly different resonance modes can be excited with a system consisting of two of these pancake coil transmitter/receivers, connected by a single “ground” wire. In his paper he described the “Herzian” frequency to lie at 4.7 MHz, while the longitudinal frequency lies at 7 MHz. In a later demonstration video, however, he showed the longitudinal frequency to lie at 7.2 MHz and the Herzian one at 4.6 MHz. These latter values calculate to a factor of about 1.56, within 0.4% of the theoretical value of $\pi/2$.

http://www.tuks.nl/pdf/Reference_Material/deltaavalon/L.M.D.%20waves%20in%20a%20Tesla%20Coil%20Revised.pdf

"To precisely detect the main frequency “fo” of the Tesla coil XMTR, a digital oscilloscope “GDS-820-S” series from “GW-Instek” was used and the related wired “probe” was placed about $d = 2$ m from the XMTR: the main resonance frequency was confirmed to be $f_0 = 2,755$ MHz with another main frequency at $f = 1,810$ MHz; it is noted that the relationship between said main frequencies is: $f_0 / f = 1,527 \text{ MHz} \approx (\pi/2)f$.

As it is:

$\lambda_0 = c / f_0$ (where c : speed of light in vacuum)

said frequency corresponds to a wave length of $\lambda_0 = 113,64\text{m}$ or to $\lambda_0/4 = 28,41\text{m}$ (or “quarter wave-length”), this means that the tests were performed in the so-called “near field”; regarding this aspect it could be objected that it would invalidate the experiment but, on the contrary, just by keeping the distance “ d ” from the XMTR much smaller than a quarter wave-length “ $\lambda/4$ ”, the T.E.M. components of the wave had less possibility of influencing the test, thus allowing the L.M.D. components to mainly play.”

From this short overview it is obvious that faster than light propagation of electric signals have been observed and demonstrated for almost two centuries, yet somehow have been ignored by main stream science, even though an obvious flaw in the Maxwell-Heaviside equations has been known about for almost just as long.

Theoretical background

Over the years, the obvious flaw in the Maxwell-Heaviside equations in that these fail to predict the two currently known types of electromagnetic waves have never been corrected, which has led to a lot of problems in theoretical physics.

The first major problem that arose is that the Maxwell-Heaviside equations cannot be transformed using the Galilean coordinate transform, which led to the invention of the Lorentz transform. It is this rather strange transform that demands a universally fixed speed of light, which eventually led to Einstein’s General Theory of Relativity wherein space itself is proposed to be curved and time itself is proposed to be relative, all in order to be able to adhere to an unwarranted universal speed limit.

The second major problem that arose is that the magnetic vector potential **A** has not been uniquely defined in the Maxwell-Heaviside equations. The current definition allows the arbitrarily addition of curl-free components to the magnetic potential without changing the observed magnetic field, which introduces an unwarranted degree of freedom in the choice for the magnetic vector potential **A**. This became known as gauge invariance and on the basis of this obvious flaw a whole range of mathematical theories have been developed, which were eventually included in the Standard Model as a “non-abelian gauge theory with the symmetry group $U(1) \times SU(2) \times SU(3)$ ”, which predicts a total of twelve “gauge bosons” to exist: the “photon”, three “weak bosons” and eight “gluons”.

In 1996, Paul Stowe published his paper “A Foundation for the Unification of Physics”, wherein he showed that all of the known constants that describe all electromagnetic phenomena can be derived from a single hypothesis, namely an aether hypothesis. He started out by defining a Newtonian loss-free fluid model for describing the medium/aether and working that out in a consistent manner using well established math.

Of course, Stowe’s aether model can also be described in vector notation and since this model essentially describes a fluid/gas like medium, we can apply fluid dynamics vector theory to re-derive the Maxwell-Heaviside equations from the basic hypothesis/model. As is common practice in fluid dynamics vector theory, we can describe it’s dynamic behavior by working with the medium flow velocity vector field **v**.

In order to derive wave equations from this basic model, all we need to do is to apply the vector Laplacian to this velocity vector field **v**:

$$\nabla^2 \mathbf{v} = \nabla(\nabla \cdot \mathbf{v}) - \nabla \times (\nabla \times \mathbf{v})$$

We can work this out by writing out the above terms in their components and giving these their familiar names and historic signs. Thus, we define a vector field **A** for the **magnetic potential**, a scalar field Φ for the **electric potential**, a vector field **B** for the **magnetic field** and a vector field **E** for the **electric field** by:

$$\begin{aligned}\mathbf{A} &= \nabla \times \mathbf{v} \\ \Phi &= \nabla \cdot \mathbf{v} \\ \mathbf{B} &= \nabla \times \mathbf{A} = \nabla \times (\nabla \times \mathbf{v}) \\ \mathbf{E} &= -\nabla \Phi = -\nabla (\nabla \cdot \mathbf{v})\end{aligned}$$

According to the Helmholtz theorem, $\mathbf{v}$ is uniquely specified by Φ and **A**. And, since the curl of the gradient of any twice-differentiable scalar field Φ is always the zero vector, $\nabla \times (\nabla \Phi) = \mathbf{0}$, and the divergence of the curl of any vector field **A** is always zero as well, $\nabla \cdot (\nabla \times \mathbf{A}) = 0$, we can establish that **E** is **curl-free** and **B** is **divergence-free**, and we can write:

$$\begin{aligned}\nabla \times \mathbf{E} &= \mathbf{0} \\ \nabla \cdot \mathbf{B} &= 0\end{aligned}$$

For the summation of **E** and **B**, we get:

$$\mathbf{E} + \mathbf{B} = -\nabla (\nabla \cdot \mathbf{v}) + \nabla \times (\nabla \times \mathbf{v}) = -\nabla^2 \mathbf{v},$$

which thus gives the negated vector Laplacian for $\mathbf{v}$.

Since $\mathbf{v}$ is uniquely specified by Φ and **A**, and vice versa, we can establish that with this definition, we have eliminated “gauge freedom” and since we know these equations can be transformed using the Galilean coordinate transform, we have also eliminated the need for the Lorentz transform and thus no longer need to revert to the concept of “curved space” in order to straighten things out, while we are also no longer bound by the universal speed limit demanded by the Lorentz transform.

With this straightforward application of well established math, we have thus come to a revised version of the Maxwell-Heaviside equations that not only resolves all of the problems that have been found over the years, we also obtain a model that is easy to interpret and can be easily simulated and visualized with finite-difference time-domain methods (FDTD) as well.

As we know from fluid dynamics, our revised Maxwell-Heaviside equations predict three types of wave phenomena to occur, which we can now easily relate to the observed phenomena:

1. Longitudinal pressure waves, Tesla’s faster than light waves c.q. the FTL longitudinal dielectric mode;
2. Transverse waves, occurring at the boundary of two media with different densities such as the metal surfaces of an antenna and air, aka the “near field”;
3. Vortices and/or vortex rings, the “far field”, which is known to be quantized and to incorporate a thus far mysterious mixture of “particle” and “wave” properties, the so called “wave particle duality” principle.

Since the far field as emitted by an EM mode antenna consists of expanding vortices and/or vortex rings, whereby the medium moves in circles/spirals, while with longitudinal dielectric waves the medium moves translational, we can derive a factor describing the difference in propagation speed between the longitudinal dielectric wave and the far field as follows.

Since the medium moves in a circle, it has to cover a distance of $\pi * r$, with r the radius of the circle, while for the longitudinal wave the medium only has to cover a distance of $2 * r$. When divided, the radius falls out and thus we obtain a theoretical factor of $\pi/2$ between the propagation speed of the far field and longitudinal dielectric waves, which correlates well with available observational data.

Under normal circumstances, the near field can be considered to be a transverse wave propagating along the surface of two different media. In the case of an antenna, these are the metal the antenna is made of and the air surrounding it. In classic kinetic theory the Poisson ratio denotes the ratio of transverse contraction strain to longitudinal extension strain in the direction of stretching force, which has a theoretic value between -1 and 0.5. For a perfectly isotropic elastic material, Poisson's ratio is 0.25. For this case, longitudinal waves propagate a factor $\sqrt{3}$ times as fast as transverse waves. This leads to a theoretical velocity factor/ratio between near field transverse waves and far field waves of $\frac{\pi/2}{\sqrt{3}}$, or about 0.91. This velocity factor needs to be taken into account when designing antenna's, although the factor also depends on the material the antenna is made of and is usually higher than 0.91.

However, Elmore has shown that besides the common transverse near field wave that radiates into the far field, also a non radiating longitudinal electric, transverse magnetic mode exists which propagates at velocity of c along a single conductor. He has also shown that such a single wire transmission line has an impedance equal to that of free space, or about 377Ω . This mode is very similar to the FTL longitudinal dielectric mode and has a very high bandwidth combined with very low losses and can be applied for high speed data transmission along existing power lines as well as for low loss transmission of power along a single conductor.

In order to design an antenna or transmission line for the FTL longitudinal mode, we need to determine the characteristic impedance of the transmission line, which equals that of free space. For the transverse electromagnetic (TEM) mode (far field), the following equation holds:

$$c = \frac{1}{\sqrt{\mu_{TEM} \epsilon}} = \frac{Z}{\mu_{TEM}}$$

Since the propagation speed for the longitudinal dielectric FTL mode equals $\frac{\pi}{2} c$, we can work out the value for the translational permeability μ_{LD} in relation to the known rotational magnetic permeability μ_{TEM} :

$$\mu_{LD} = \frac{4}{\pi^2} \mu_{TEM}$$

With this, we can also work out the free space impedance for the FTL longitudinal dielectric mode:

$$Z_{LD} = \sqrt{\frac{\mu_{LD}}{\epsilon}} = \sqrt{\frac{4 \mu_{TEM}}{\pi^2 \epsilon}} \approx 240 \Omega$$

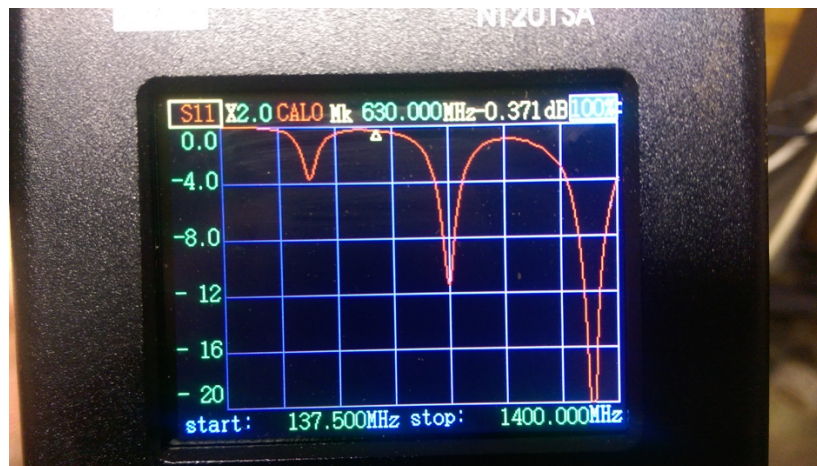
I did some measurements with an 28 cm long coil wire, to which I soldered a trim capacitor at one side and adjusted it to the minimum capacitance, which I can hardly measure, but it appears to be around 1 pF, +/- 0.5 pF. I can attach either end of the wire to the inner terminal of the connector and see what happens.

First, I looked at the S11 parameters.

This is what it looks like when I connect the non-capacitor side to the analyzer:

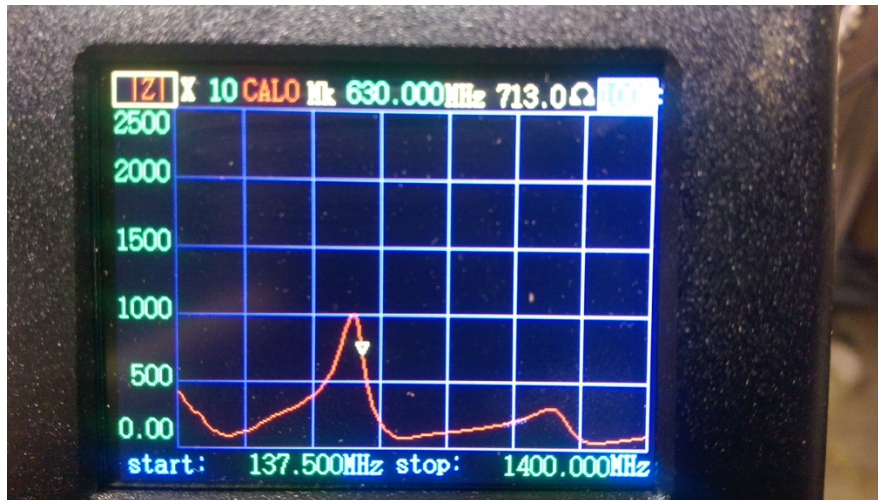


With capacitive coupling, this is what happens:

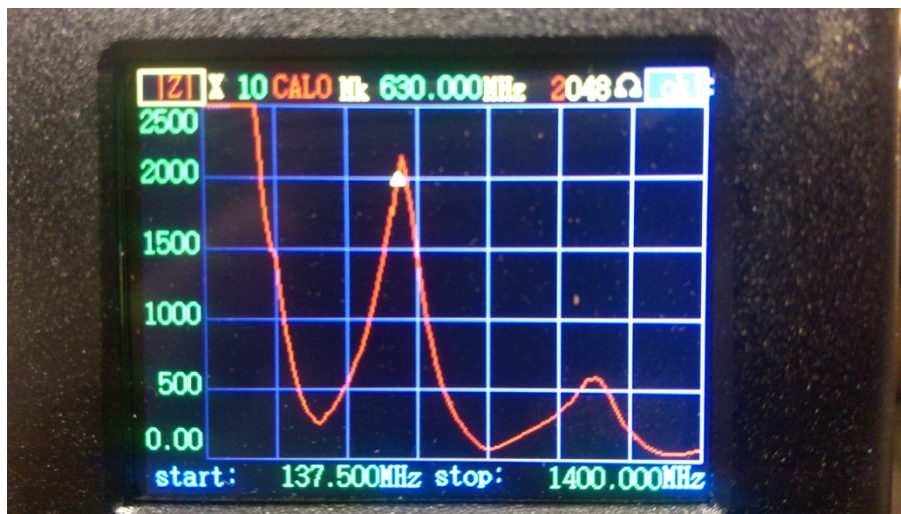


So, no extra dips, but the dips do shift higher in frequency.

Then, I looked at the impedance. Direct coupled:



Capacitively coupled:



So, the impedance increases significantly right in between the dips, which becomes stronger when I add (loose) capacitive coupling.

This may be significant, although I don't yet know what to make of it, although it probably has to do with series/parallel resonances:

<http://pediaa.com/difference-between-series-and-parallel-resonance/>

"Difference Between Series and Parallel Resonance

Impedance

At the resonant frequency, a series RLC circuit has the minimum impedance, whereas a parallel RLC circuit has maximum impedance.

Current

At the resonant frequency, a series RLC circuit has the maximum current, whereas a parallel RLC circuit has [minimum current]."

<https://www.electronics-tutorials.ws/accircuits/series-resonance.html>

"We can see then that at resonance, the two reactances cancel each other out thereby making a series LC combination act as a short circuit with the only opposition to current flow in a series resonance circuit being the resistance, R . In complex form, the resonant frequency is the frequency at which the total impedance of a series RLC circuit becomes purely "real", that is no imaginary impedance's exist. This is because at resonance they are cancelled out. So the total impedance of the series circuit becomes just the value of the resistance and therefore: $Z = R$."

<https://www.electronics-tutorials.ws/accircuits/parallel-resonance.html>

"Notice that at resonance the parallel circuit produces the same equation as for the series resonance circuit. Therefore, it makes no difference if the inductor or capacitor are connected in parallel or series.

Also at resonance the parallel LC tank circuit acts like an open circuit with the circuit current being determined by the resistor, R only. So the total impedance of a parallel resonance circuit at resonance becomes just the value of the resistance in the circuit and $Z = R$ as shown."

I found two sources, wherein the telegraph equations are explained for the case of a long wire over a ground plane, which accordingly can be applied for a near field consideration of an antenna, layed out parallel with the ground as in Dollard's velocity measurement experiment:

http://www.ittc.ku.edu/~jstiles/723/handouts/2_1_Lumped_Element_Circuit_Model_package.pdf

<https://www.witpress.com/Secure/elibrary/papers/9781845640637/9781845640637001FU1.pdf>

"The problem of an external electromagnetic field coupling to an overhead line can be solved using a number of approaches. One such approach makes use of antenna theory, a general methodology based on Maxwell's equations [1]. Different methods based on this approach generally use the thin-wire approximation, in which the wire's cross section is assumed to be much smaller than the minimum significant wavelength.

When electrically long lines are involved, however, the antenna theory approach requires prohibitively long computational times and high computer resources. On the other hand, the less resource hungry quasi-static approximation [1], in which propagation is neglected and coupling is described by means of lumped elements, can be adopted only when the overall dimensions of the circuit are smaller than the minimum significant wavelength of the electromagnetic field. For many practical cases, however, this condition is not satisfied.

[...]

A third approach is known as transmission line theory. The main assumptions for this approach are as follows:

1. Propagation occurs along the line axis.
2. The sum of the line currents at any cross section of the line is zero. In other words, the ground – the reference conductor – is the return path for the currents in the n overhead conductors.
3. The response of the line to the coupled electromagnetic fields is quasi-transverse electromagnetic (quasi-TEM) or, in other words, the electromagnetic field produced by the electric charges and currents along the line is confined in the transverse plane and perpendicular to the line axis.

If the cross-sectional dimensions of the line are electrically small, propagation can indeed be assumed to occur essentially along the line axis only and the first assumption can be considered to be a good approximation.

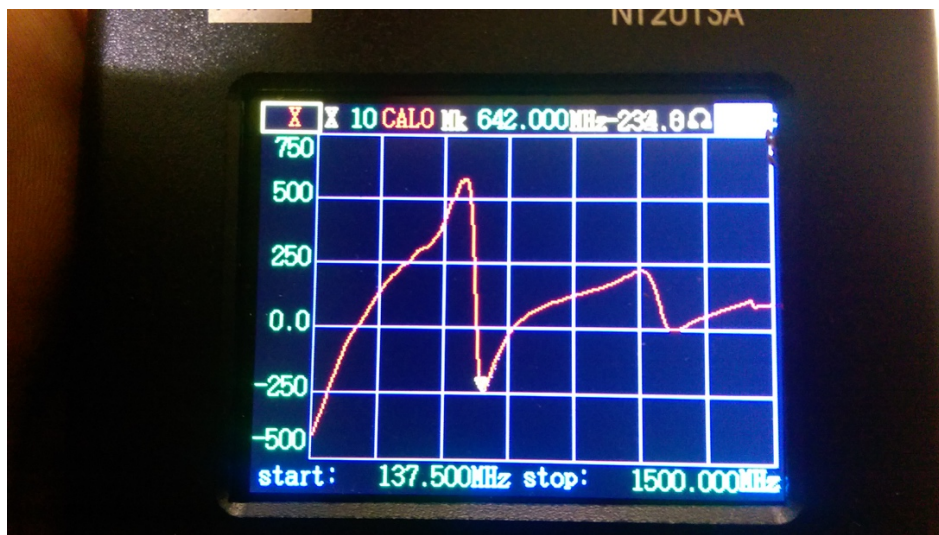
The second condition is satisfied if the ground plane exhibits infinite conductivity since, in that case, the currents and voltages can be obtained making use of the method of images, which guarantees currents of equal amplitude and opposite direction in the ground.

The condition that the response of the line is quasi-TEM is satisfied only up to a threshold frequency above which higher-order modes begin to appear [1]. For some cases, such as infinite parallel plates or coaxial lines, it is possible to derive an exact expression for the cutoff frequency below which only the TEM mode exists [3]. For other line structures (i.e. multiple conductors above a ground plane), the TEM mode response is generally satisfied as long as the line cross section is electrically small [3]. Under these conditions, the line can be represented by a distributed-parameter structure along its axis."

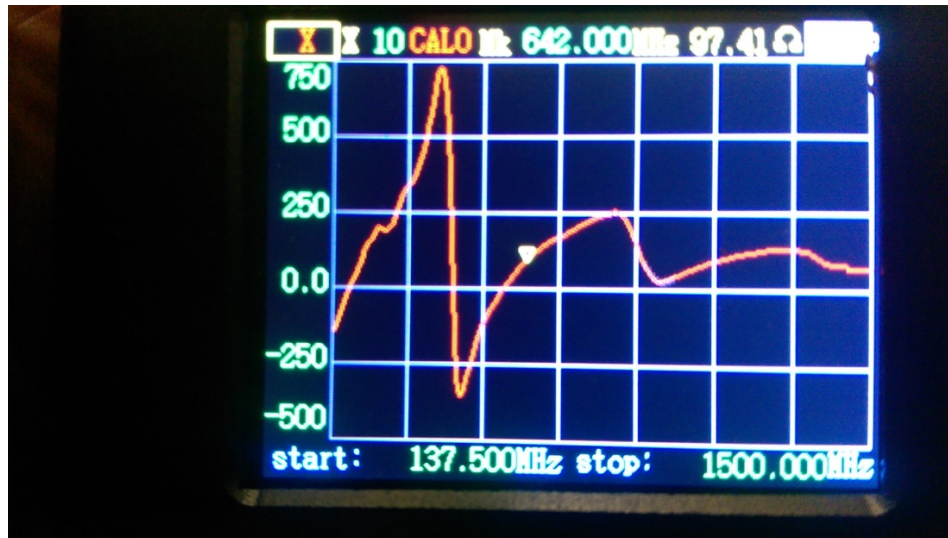
What happens when I close the antenna wire with a capacitive load (sphere, disk)?

When I continued measuring, I noted that the reactance rather suddenly jumps from positive (inductive) to negative (capacitive) right at the point where you get a maximum (absolute) impedance.

Here the reactance for a bare wire of about 30 cm:



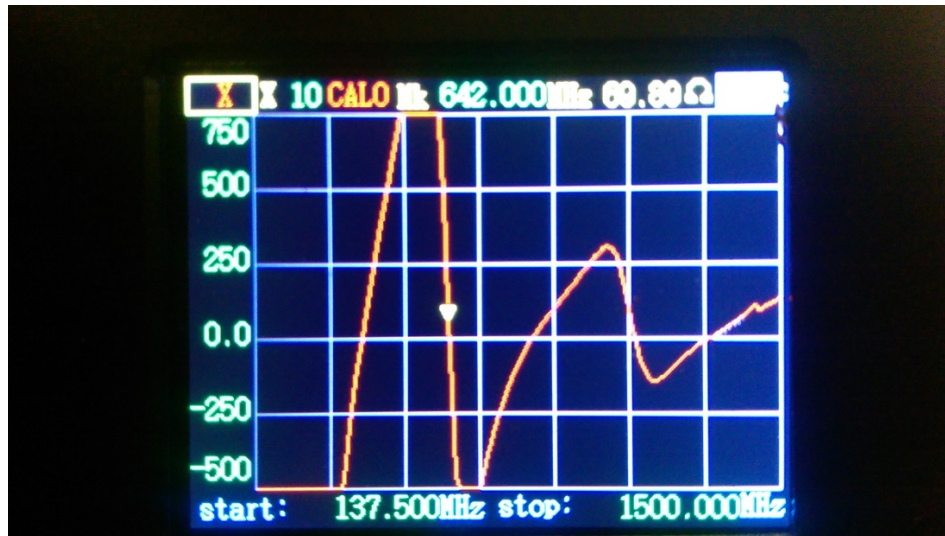
The same wire with a capacitive load at the top (some aluminum foil, wrapped around a plastic cup):



The 28 cm wire I used before with the trim capacitor at the top:



And connected the other way (capacitively coupled):

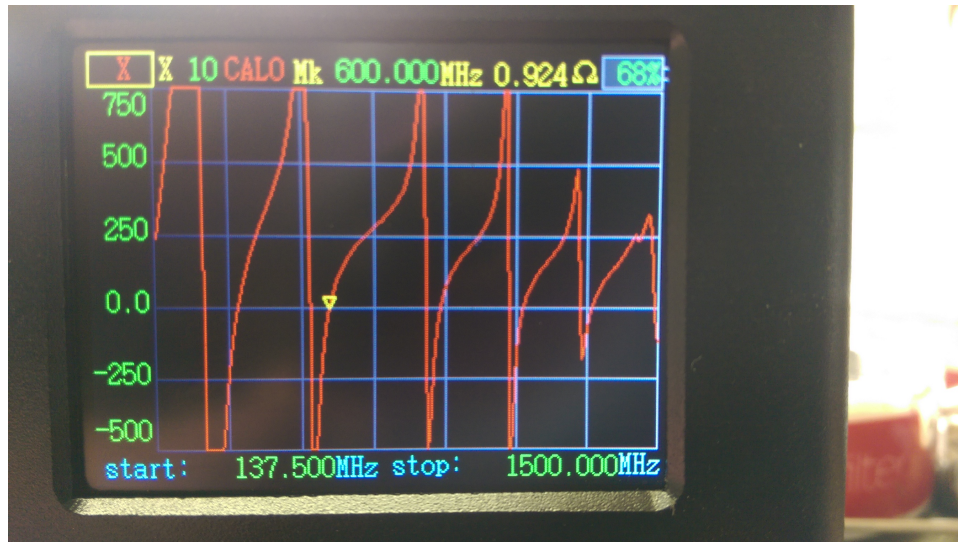


And finally, a helical, wound from the same kind of wire, 20 turns, inner diameter 7.5 mm, length about 48 mm, wire diameter 0.9 mm, inductance 1.5 uH:



I found the results with the helical rather surprising and interesting, because with a helical you have distributed inner-turn capacitance and with this, the sudden discontinuity in the reactance, suddenly jumping from positive (inductive) to negative (capacitive), is quite profound.

I made a pancake coil as well. 7 turns, outer diameter about 5 cm, inductance about 1.1 uH, which I connected from the centre terminal. It shows the same behavior:



Do the measurements so far imply there is no resonance at the maximum impedance c.q. reactance sign jump, or is there resonance but is it just hardly radiating because of the high impedance?

As far as I can tell now, we're gonna need an impedance transformer if we want to be able to radiate any power to speak of with this mode, which could be done with a pancake transformer. Since we would go from a feed impedance of 50 Ohm to an antenna impedance in the order of 2 kOhm, we would probably be talking about a secondary with in the order of 40 turns or so, if we use a magnetic loop of 1/1 lambda as primary. I made a sketch in that direction years ago:

http://www.tuks.nl/img/TeslaTM_1296_MHz.jpg

1296 MHz. Lamare 3/4/2012
 $\lambda_T = 23,2 \text{ cm}$ $\lambda_L = 36,3 \text{ cm}$
 $\times 0,95 = 22 \text{ cm}$ $\times 0,95 = 34,5 \text{ cm}$

$$\frac{1}{4} \lambda_L = 8,625 \text{ cm}$$

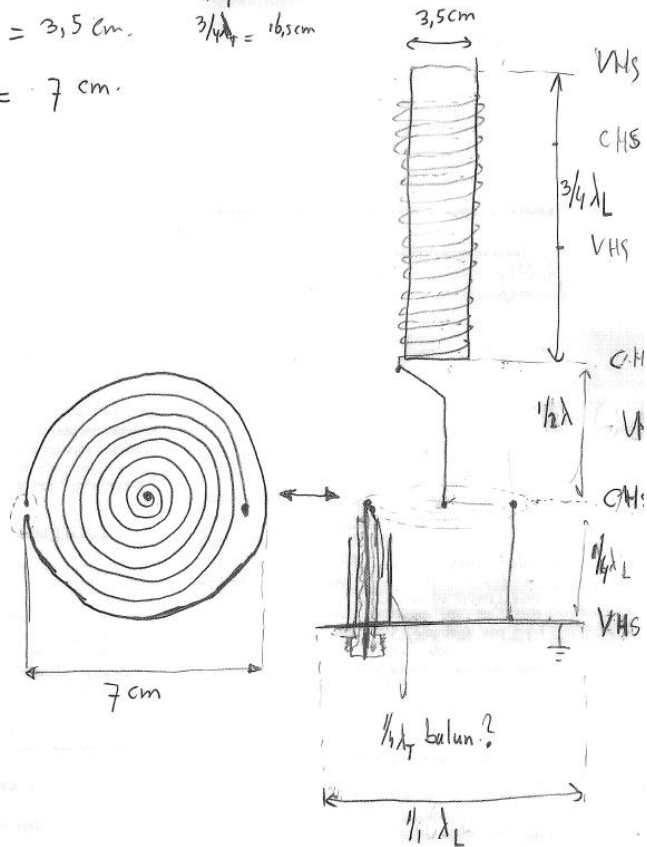
$$\frac{3}{4} \lambda_L = 25,9 \text{ cm}$$

$$D_{\text{helix}} = \frac{22}{2} / \pi = 3,5 \text{ cm}$$

$$\frac{1}{4} \lambda_T = 5,5 \text{ cm}$$

$$\frac{3}{4} \lambda_T = 16,5 \text{ cm}$$

$$D_{\text{Loop}} = 22 / \pi = 7 \text{ cm}$$



In order to avoid problems with the "earth" connection of the secondary and to use the ground plane as reflecting mirror, we would have to place the pancake transformer $1/4$ lambda above the ground plane and choke the "earth" connection of the secondary with a sleeve/skirt/bazooka "balun". Probably, we would also have to enclose the transformer within a $1/4$ (or $3/4$) lambda height LE_TM mode waveguide, designed at a phase constant of zero, in order to prevent TEM radiation.

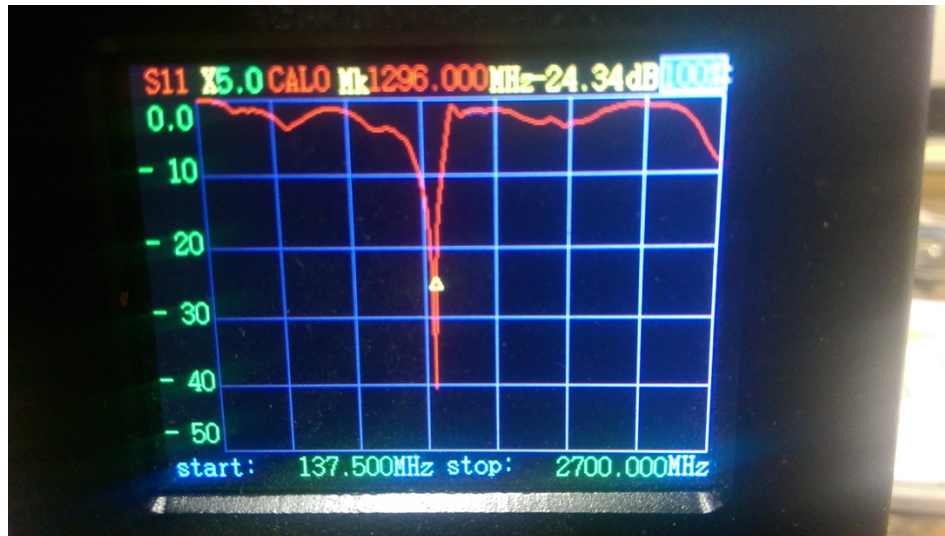
All in all, quite a challenge, but doable, especially because a pancake coil can be implemented on a PCB.

I built a coaxial impedance transforming section (to transform to 240 Ohm @1.3 Ghz) with balun and coupled it with an $1/2 \lambda_s$ whip:

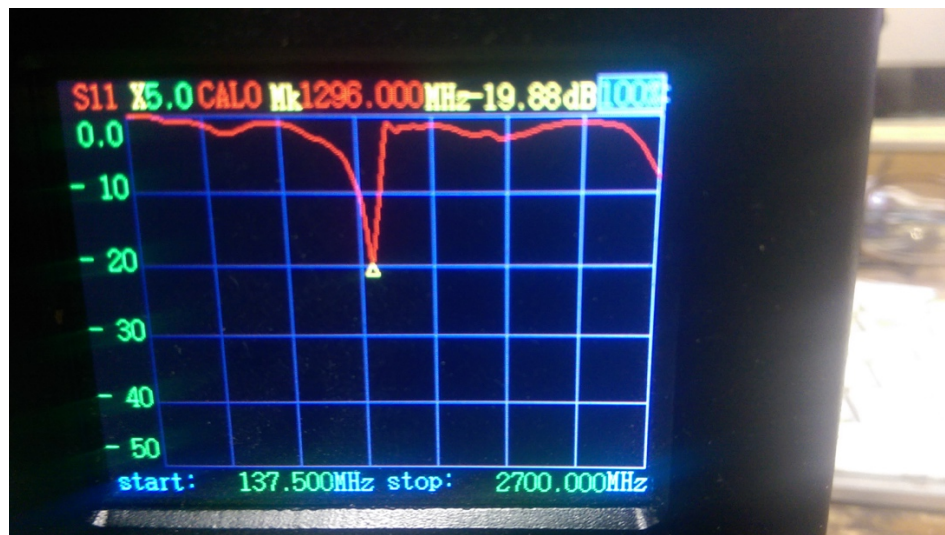


Unfortunately, I broke one of the trim capacitors you see on the pic, so I can only build one at the moment, but I've ordered 6 more (all that were left).

When I tune the capacitor, I can get a nice dip around the design frequency:

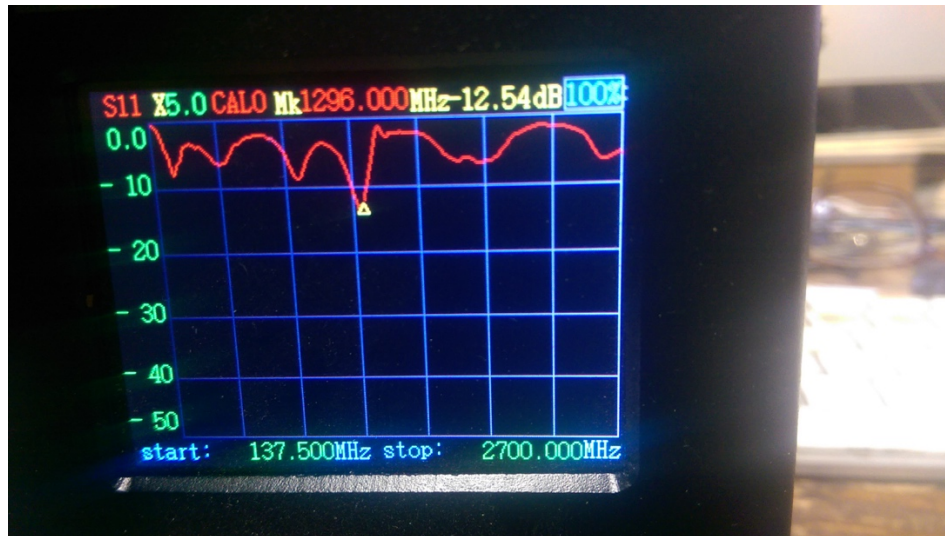


When I decrease the capacitance, this is what happens:



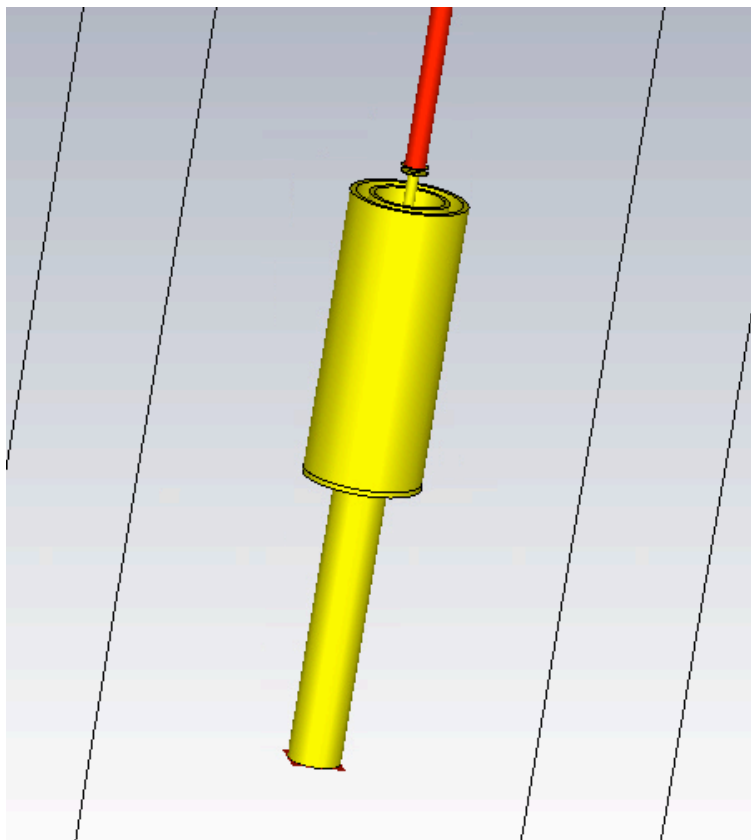
The dip becomes a bit less deep, but the overall shape of the curve remains pretty much the same. Note that there is only one significant dip across the frequency range.

When I turn it all the way in (max capacitance, should be about 3 pF) this is what happens:



What we see is that additional dips begin to appear, while the dip at 1.3 GHz begins to disappear.

I've also run a simulation for this thing:



Algorithm: Nelder Mead Simplex Algorithm
Number of evaluations: 217
(solver: 216, reloaded: 1)

Initial goal function value = 62.7678904034
Best goal function value = 33.5777761941
Last goal function value = 33.5777761941 (reloaded)

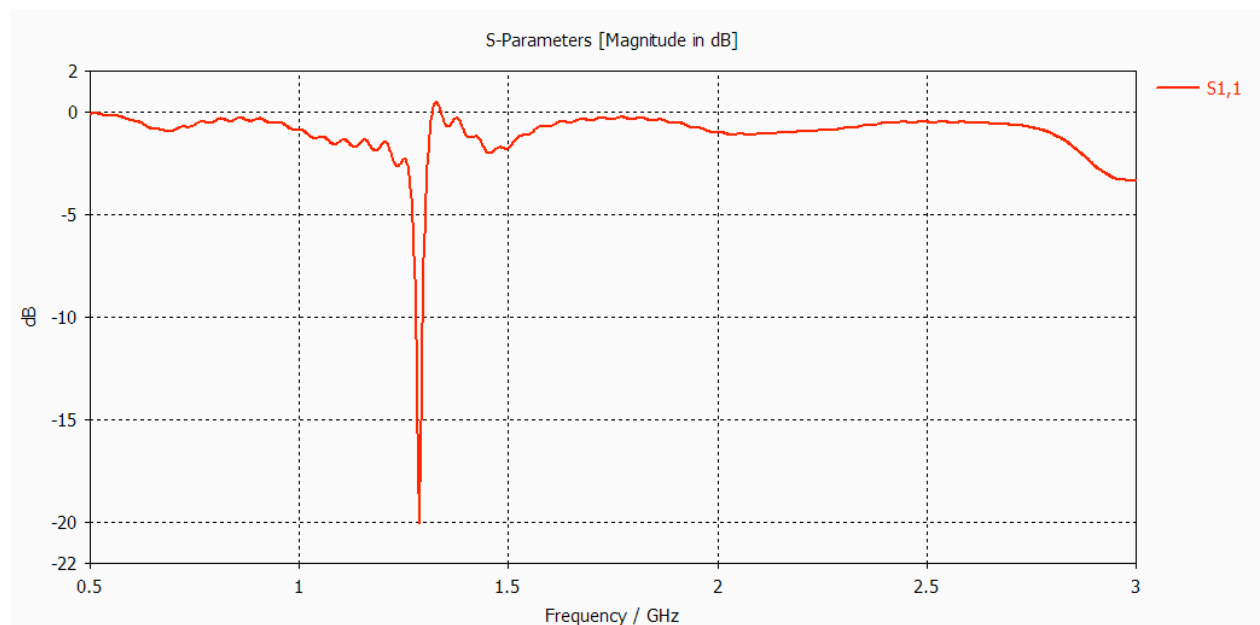
Last solver evaluation time = 00:01:12 h

Best parameters so far:

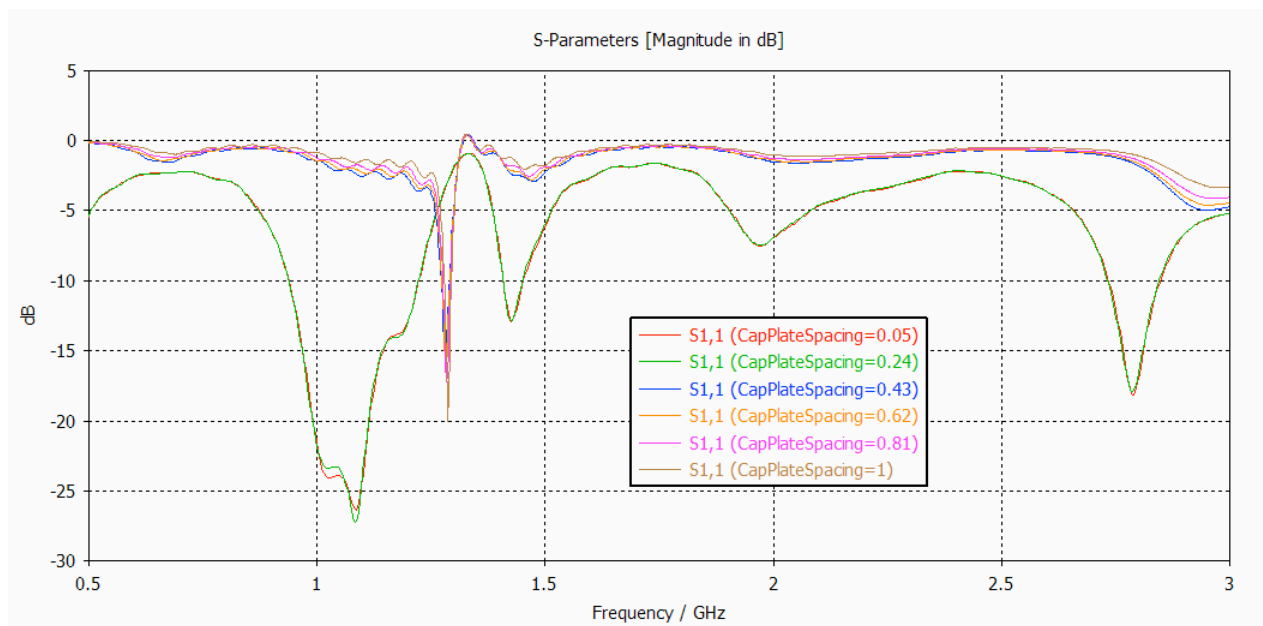
CapPlateSpacing = 2.69295
ImpMatchCoreExtraLength = 4.86345
ImpMatchLength = 53.0164
WhipLength = 179.925

(Images from earlier simulation)

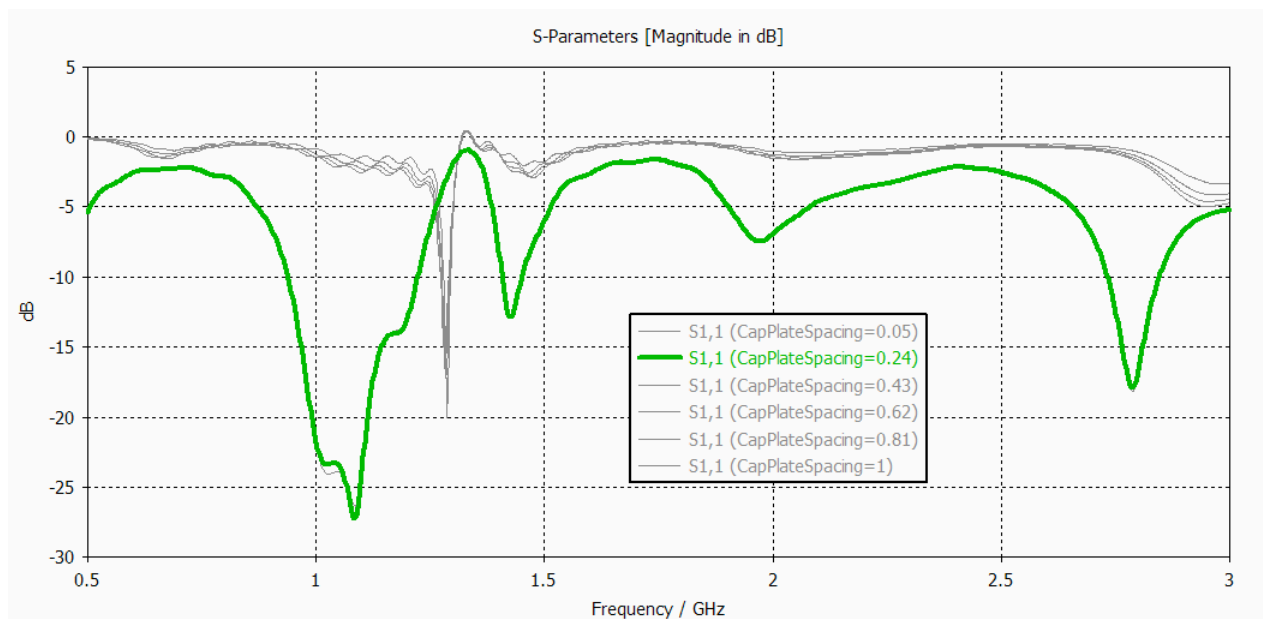
The simulator does a good job predicting the S parameters:

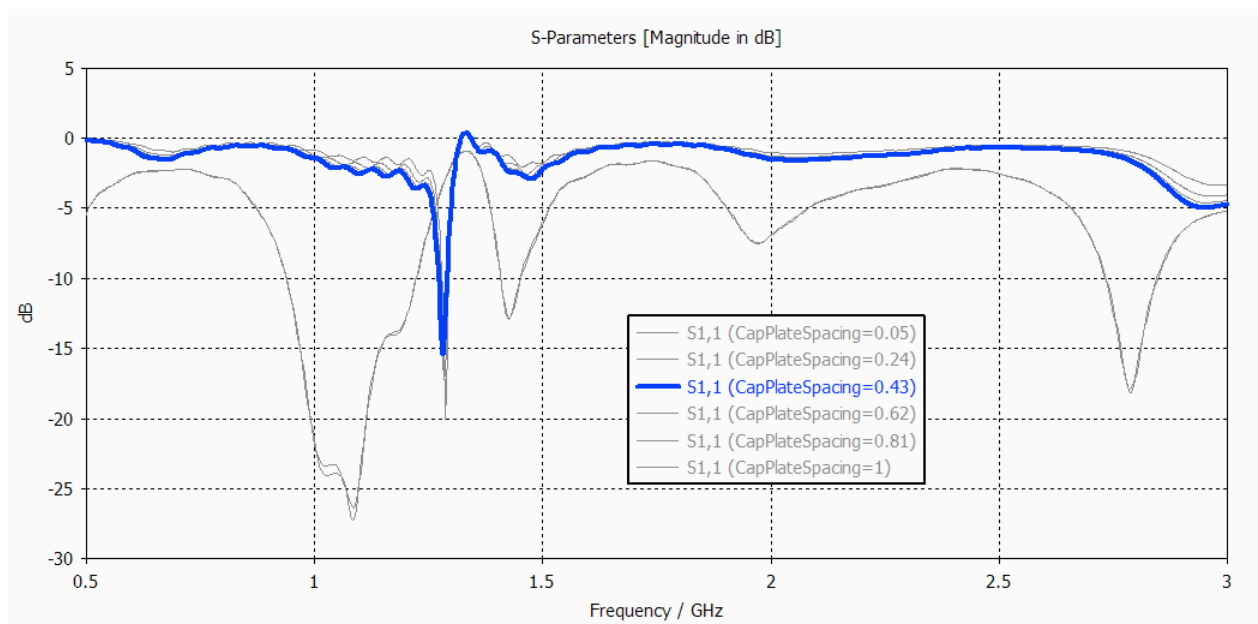


What is particularly interesting is what it predicts when I vary the capacitance by varying the plate distance:



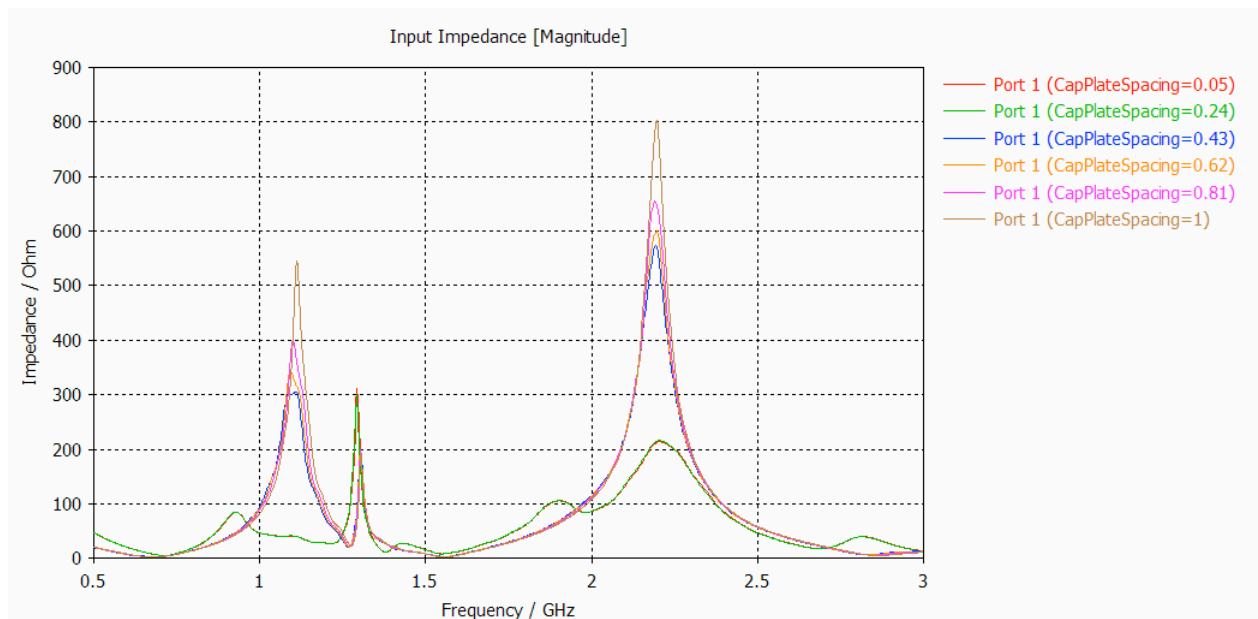
There is a rather sudden change in the S parameter curve between a plate distance of 0.24 mm and 0.43 mm. The curves for 0.05 and 0.24 mm are very close to one another, while the others are significantly different and also pretty close to one another:



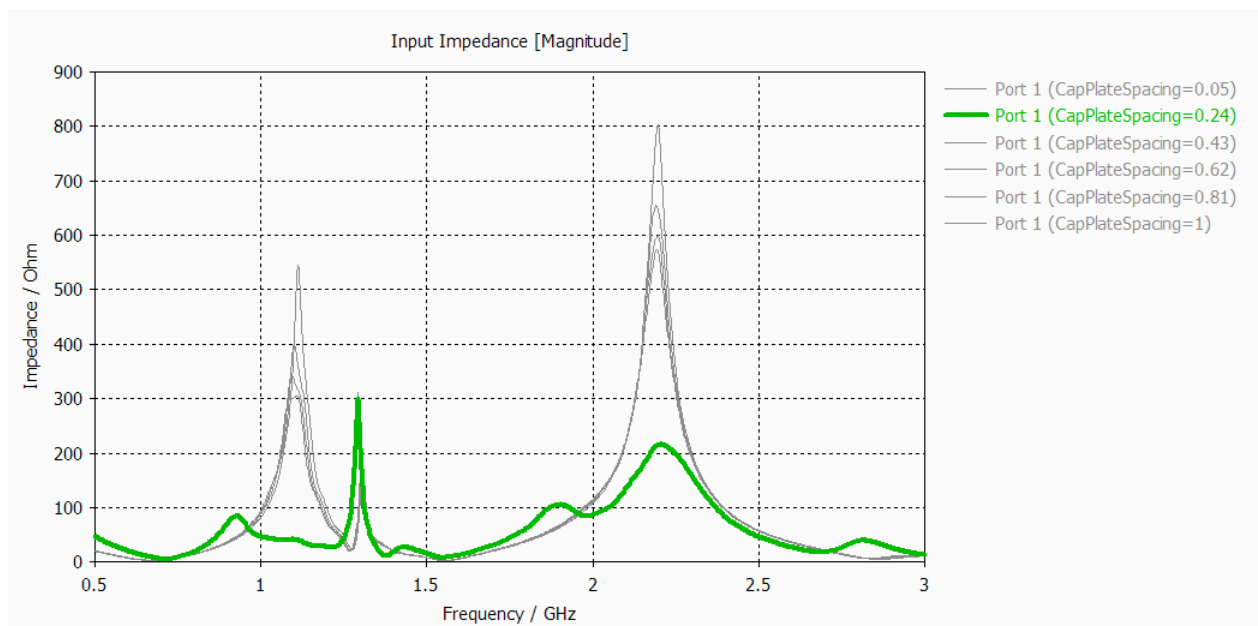


A plate distance of 0.24 mm calculates to a capacitance of about 0.8 pF, while a plate distance of 0.43 mm calculates to a capacitance of about 0.5 pF, although it should be noted that the formula used should have $d \ll r$, which is not the case here. Either way, it is pretty clear that when the coupling capacitance goes over a certain threshold you get a rather sudden and significant change in the S-parameter curve, signifying a change in propagation mode along the whip.

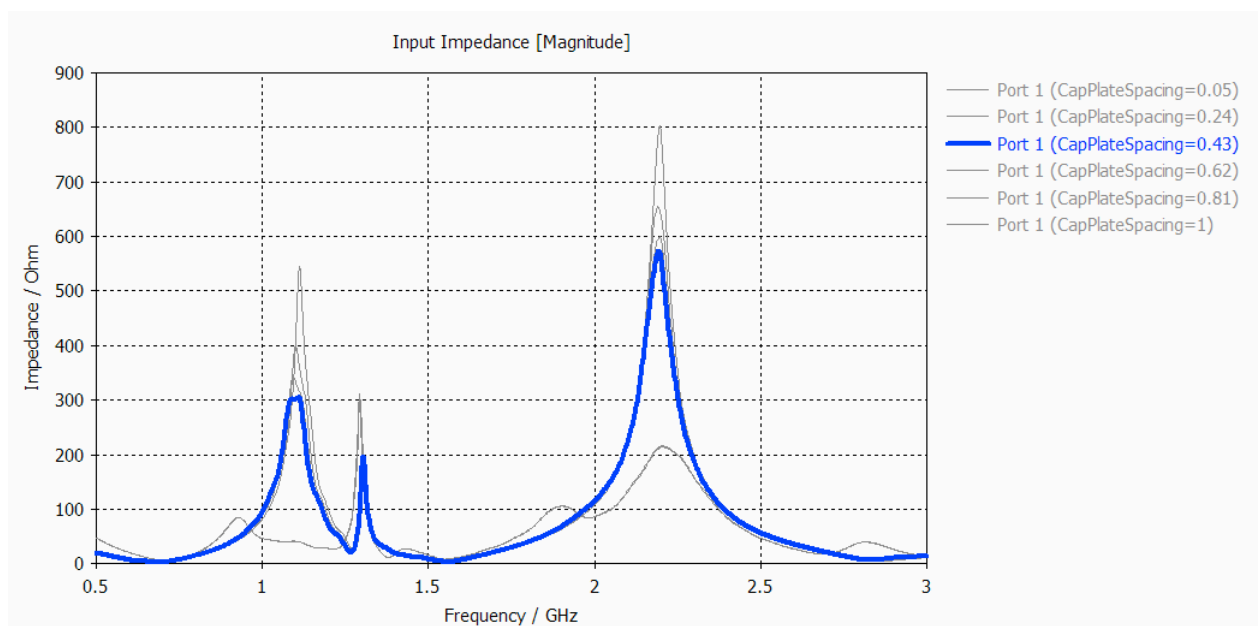
The calculated input impedance also shows a similar picture:



The curves for a plate spacing of 0.05 and 0.24 virtually lay on top of one another and there is no impedance peak around 1.3 GHz, while the peak around 2.2 GHz is relatively shallow:

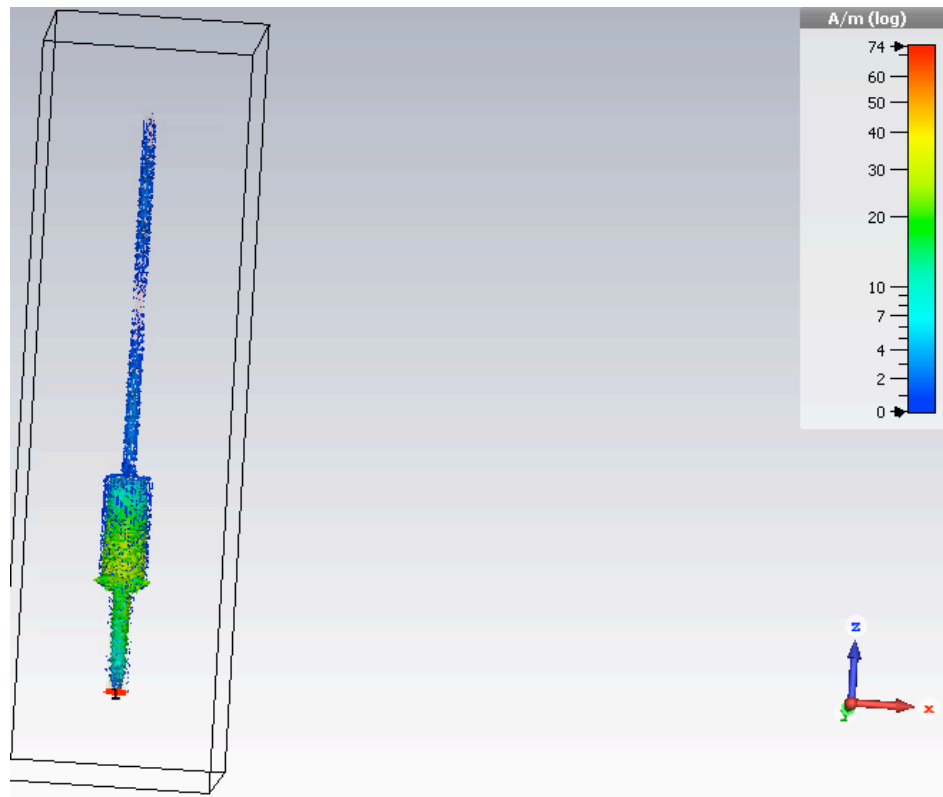


From a plate distance of 0.43 and up we get an extra peak at 1.3 GHz, while the one around 2.2 GHz becomes significantly higher:

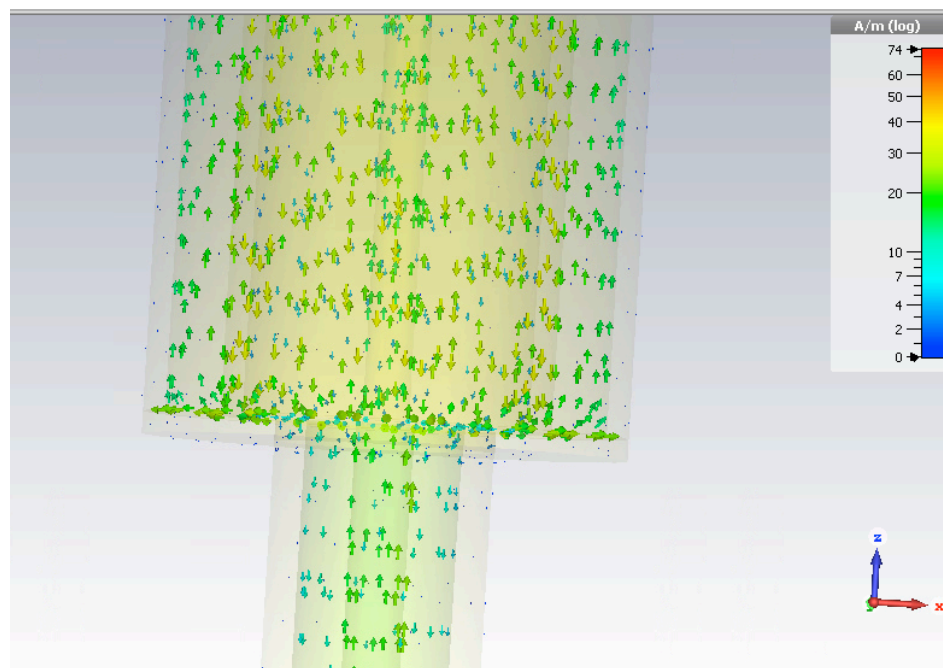


I think that from this we can conclude that in this design, the coupling capacitance plays an important role in determining the type of surface wave propagation mode we obtain along the whip.

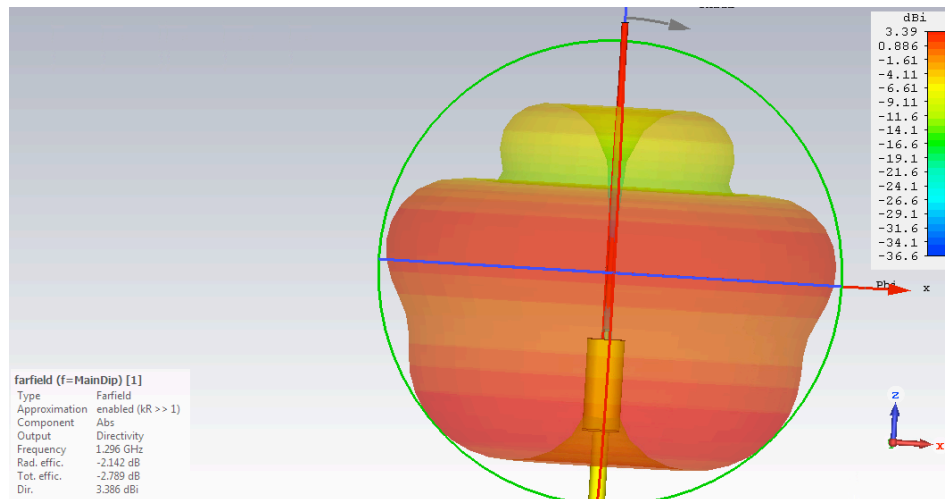
The predicted surface current is mostly contained within the balun and feed line:



While the outer surfaces of both the balun and the feedline appear cool, as they should:



Interestingly enough, though, the corresponding far-field suggests that the balun would be radiating:



I think this is rather strange and suggests we may be up to something here.