Demystifying PIT Antennas: From Theory to Practice

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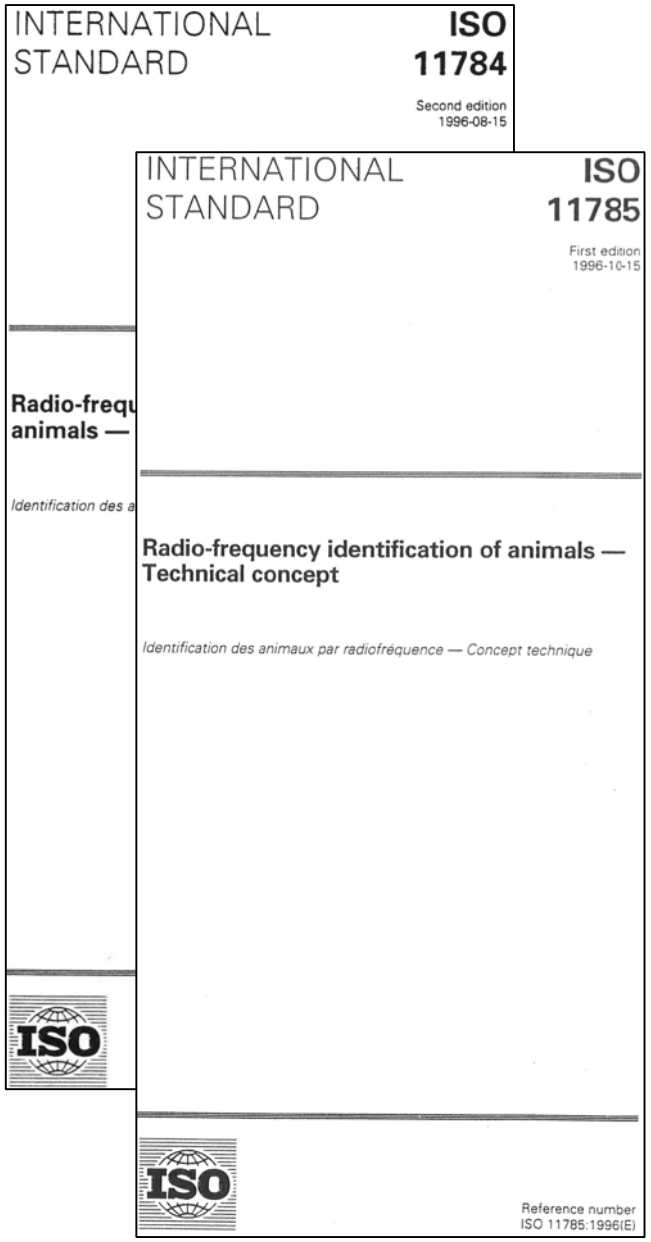
ISO11784/5

Table 1 — Summary of the FDX and HDX systems

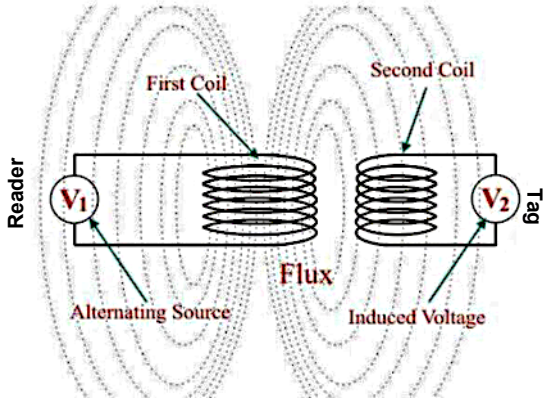
Parameter	FDX system	HDX system
Activation frequency	134,2 kHz	134,2 kHz
Modulation	AM-PSK	FSK
Return frequencies	129,0 kHz to 133,2 kHz 135,2 kHz to 139,4 kHz	124,2 kHz (1) 134,2 kHz (0)
Encoding	modified DBP	NRZ
Bit rate	4 194 bit/s	7 762,5 bit/s (1) 8 387,5 bit/s (0)
Telegram structure:		
— Header	11	8
— Identification code	64	64
— Error detection code	16	16
— Trailer	24	24
— Control bits	13	—

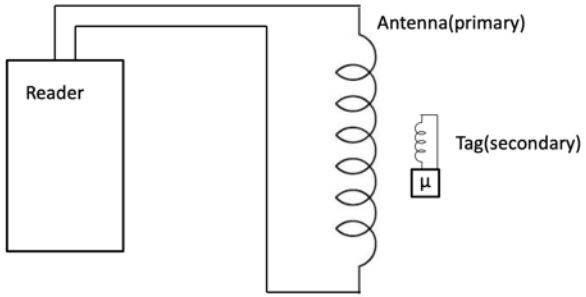


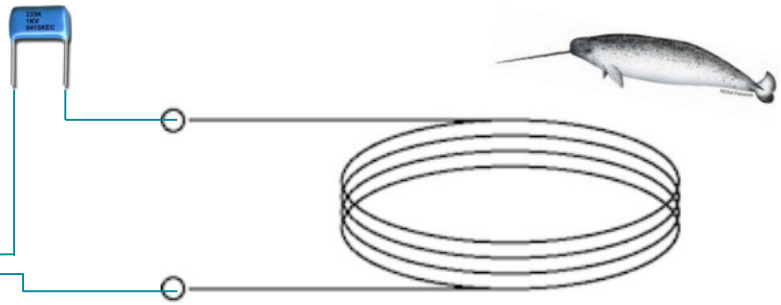
- ISO standard RFID tags (same as companion animals)
- FDX is primarily used in the CRB
  - Speed - 31.5ms (16ms Fasttag)
  - Tag size – 8mm 9mm, 12mm
- HDX is used in the CRB (lamprey)
  - Speed - 70ms (50/20)*
  - Tag size – 12mm, 23mm
- Many of the new readers deployed can read both – except FS1001-M, BCC and GRS

How a PIT tag works…

- The reader and tag act as a loosely coupled transformer
- Reader develops an EM field on the antenna
- Tag is powered up when it enters the antenna EM field and begins to operate or charge

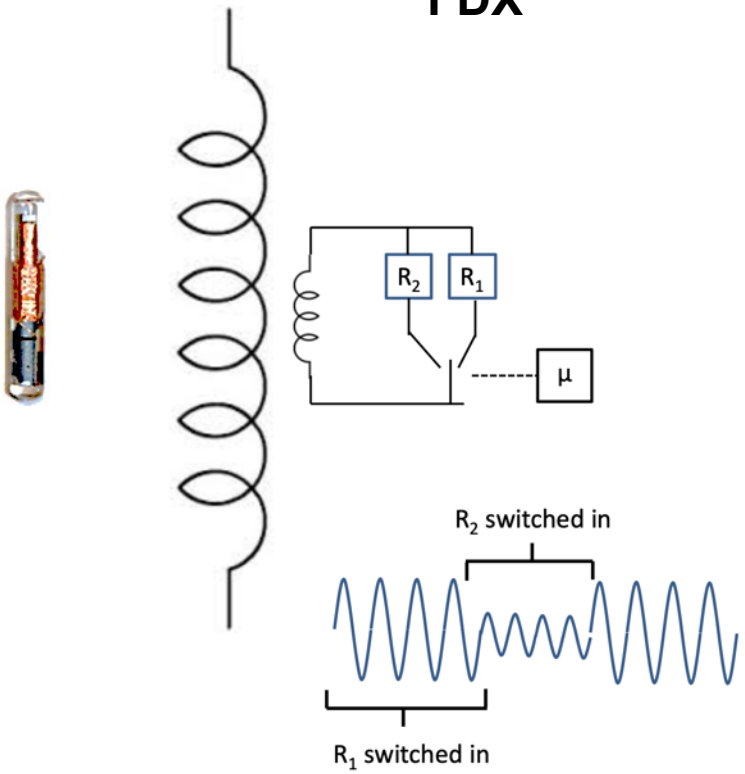






How a PIT tag works - FDX vs HDX

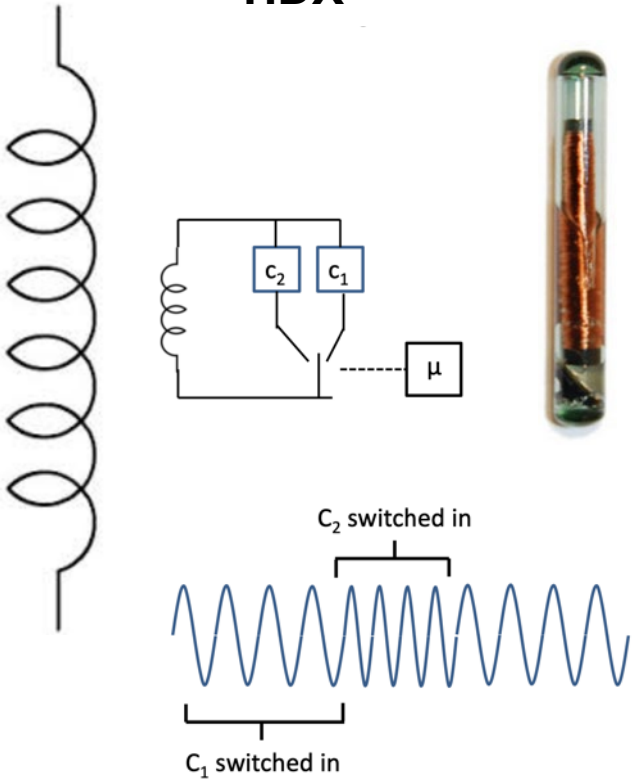
FDX



FDX

- Tag is turned on when it enters the field
- Immediately begins to “transmit”
- AM – Tag code is sent back through Amplitude Modulation (load modulation) of the antenna field

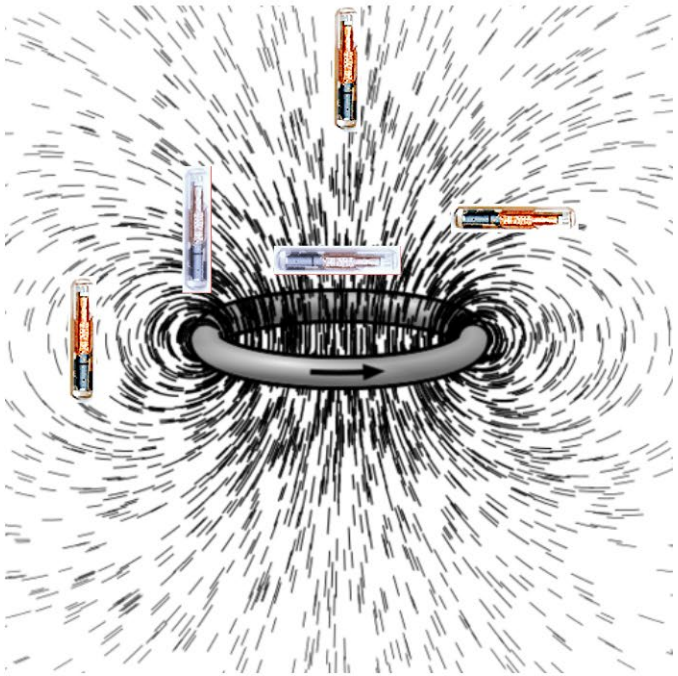
HDX

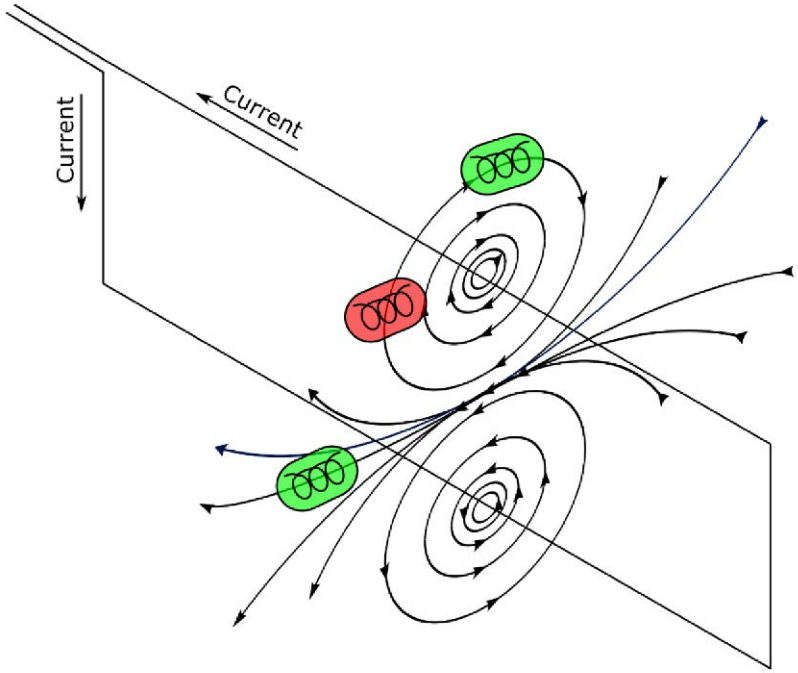


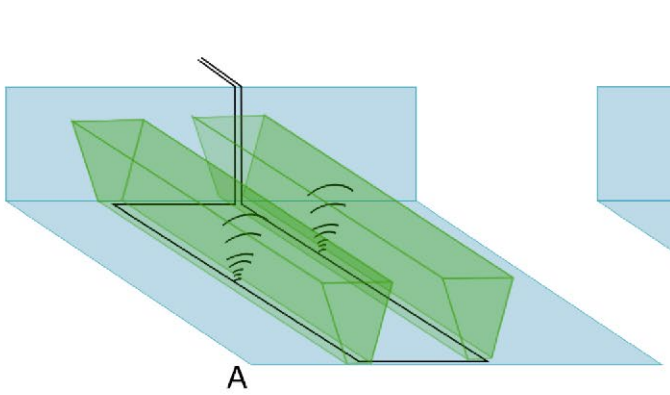
HDX

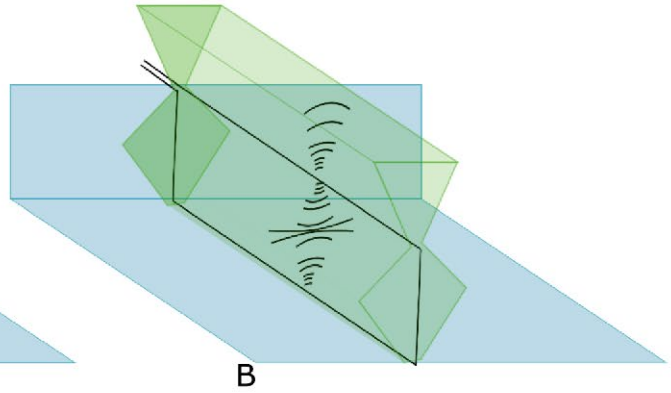
- Tag begins to charge when it enters the field (50ms)
- When the antenna turns off, the tag transmits
- FM (FSK)
  - 123.2kHz = 1
  - 134.2kHz = 0

PIT Tag Antenna Field









PIT Tag Antenna Components

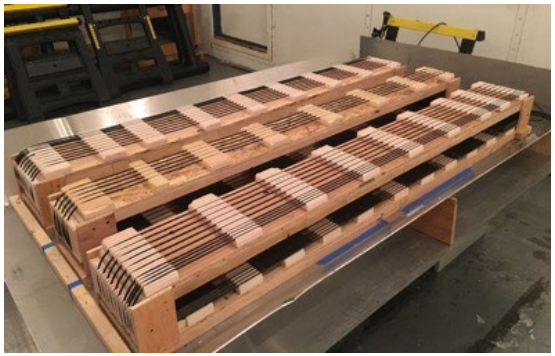
The antenna is an inductor (coil)

- Stores energy in the magnetic field when current flows through it
- Inductance is determined by the size of the inductor (antenna), the number of windings, the spacing between windings, core properties etc.

Capacitor (internal and/or external)

- Stores energy in the electrical field when a difference of potential is applied
- Readers typically have capacitance, which provides a range of values for your inductance

Building and tuning an antenna is as simple as finding the right values for each of these components



$$F = \frac{1}{2\pi\sqrt{LC}}$$

F – Resonant Frequency (134.2kHz)
L – Inductance
C - Capacitance

PIT Tag Antenna Tuning

- Maximize read range – find resonance of the antenna which means matching L and C
  - Inductor (“antenna” loop)
  - Capacitor (internal, external)
- High Q means lowest ESR (resistance)
- Skin effect (litz wire)
- Wire gauge
- Properties of insulation

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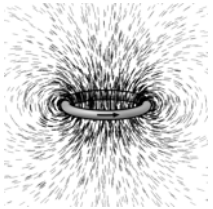
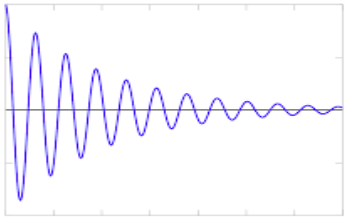
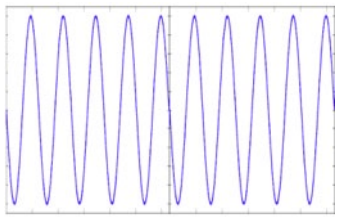


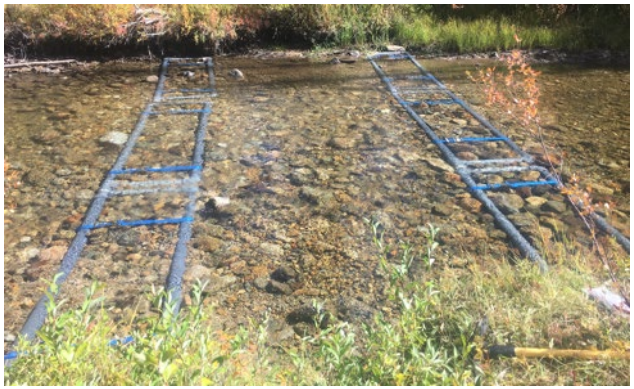


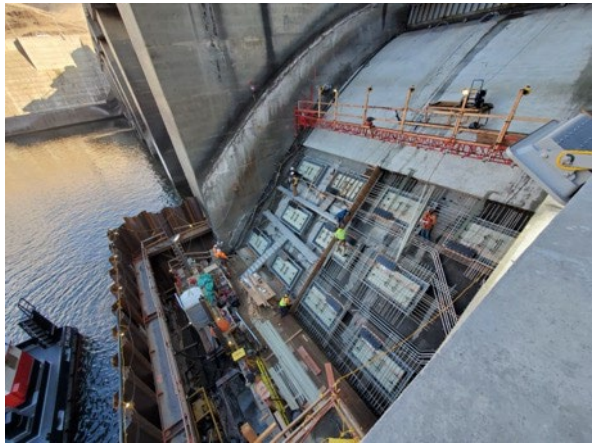
Anechoic antenna (non-resonant)



Resonant antenna

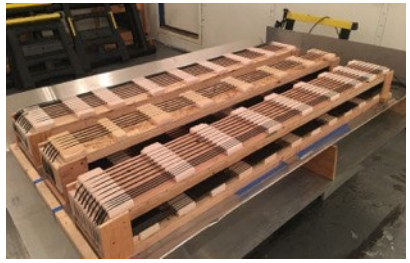
Antenna Design





Typically dictated by the reader, site, and purpose

- Pick your reader based on tags
- Type of antenna – pass-by, pass-through
- Size – 4'x5', 4'x20', 8'x20', 6'x90', 12"x12" etc.
- Determine readers acceptable inductance range
  - IS1001 ~ 140uH to 160uH (without ext. caps)
  - TI ~ 10uH to 280uH (tuning board)
  - RM310 ~220uH to 270uH (without ext. caps)
  - Wrap up a prototype and determine/measure the inductance
- Calculate the appropriate capacitance if needed, including exciter cable
- Determine a housing in some instances
- Install, troubleshoot and maintain… repeat

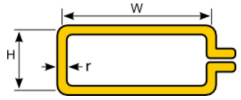


PIT Tag Antenna Tuning

- Finding the proper inductance to match your reader:
  - Establish the antenna size (i.e. 20’ x 8’)
  - Talk to the vendor about windings and spacing
  - Choose the wire size (i.e. 10awg or 2.59mm d)
  - Use a calculator and/or wrap up a prototype
  - Ask around, it’s probably been done…

LENGTH	20	ft	Select the units, ft or m					
The **HEIGHT** is the distance from centerline to centerline of the wires, typically vertical								
HEIGHT	8	ft	The units are set with **LENGTH** above.					
The PITCH is the distance from centerline to centerline of the wires of sequential turns								
10.5mm								
PITCH	10.5	mm	Select the units, in or mm					
The Capacitor Number is the tuning target for the IS1001 if a series capacitor is require								
Capacitor Number	300							
	TYPE	Ω/m						
Antenna Wire	#10 Litz	0.00344						
	TYPE	**LENGTH**		**Resistance**		**Inductance**		**Capacitance**
Antenna Cable	Pigtails only	2	ft	0.053	Ω	1.36	µH	0.083 nF

RECTANGLE LOOP INDUCTANCE CALCULATOR



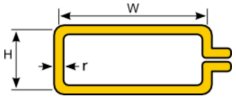
INPUTS

Number of Turns	N	3	
Loop Width	W	96	inch
Loop Height	H	240	inch
Wire Diameter	d	.259	inch
Relative Permeability	µR	1	

OUTPUT

Inductance: 0.000191 H

RECTANGLE LOOP INDUCTANCE CALCULATOR



INPUTS

Number of Turns	N	15	
Loop Width	W	75	mm
Loop Height	H	295	mm
Wire Diameter	d	.2	mm
Relative Permeability	µR	1	

OUTPUT

Inductance: 0.000211 H

https://www.eeweb.com/tools/rectangle-loop-inductance/

# TURNS	Antenna Inductance			Range
	Alone	+ Cable		
1	22.3	23.7	µH	TOO LOW
2	79.9	81.3	µH	JP1 IN
3	167.4	168.8	µH	JP1 OUT +
4	282.0	283.4	µH	JP1 OUT +
5	421.7	423.0	µH	JP1 OUT +
6	584.9	586.2	µH	JP1 OUT +
7	770.4	771.8	µH	TOO HIGH
8	977.3	978.6	µH	TOO HIGH

less inductance

more inductance

less inductance

more inductance

less inductance

air core
(permeability = 1)

more inductance

soft iron core
(permeability = 600)

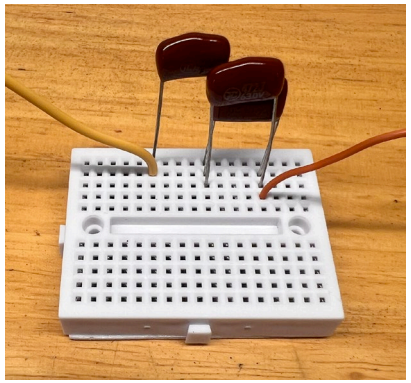
Allaboutcircuits.com

$$F = \frac{1}{2\pi\sqrt{LC}}$$

F – Resonant Frequency
L – Inductance
C - Capacitance

PIT Tag Antenna Tuning

- Finding the proper capacitance
  - Several calculators exist – Steinke, NOAA etc.
  - Breadboard capacitors and test



C_{EXT} Target	16																							
	C_{EXT}	C1	C2	C3	C4	C5	C6		C_{EXT}	C1	C2	C3	C4	C5	C6		C_{EXT}	C1	C2	C3	C4	C5	C6
	2.35			4.7	4.7				8.77	4.7	3.3	3.3	1				20.50	10	10	1	1		
	2.42			2.2	2.2	2.2	3.3		9.50	4.7	3.3	4.7	2.2				21.00	10	10	1	JPR		
	2.48			3.3	10				10.35	4.7	3.3	4.7	4.7				22.00	22					
	2.57			1	3.3	2.2	10		11.00	10	1						23.00	22	1				
	2.69	1	1	1	2.2				11.50	10	1	1	1				24.00	22	1	1	JPR		
	2.80	1		2.2	10				12.00	10	1	1	JPR				25.20	22	2.2	1	JPR		
	2.90			2.2	2.2	2.2	10		12.35	10		4.7	4.7				26.30	22	3.3	1	JPR		
	3.00	1	1	1	JPR				12.70	4.7	4.7	3.3	JPR				27.52	22	4.7	1	4.7		
	3.10	1	1	2.2	2.2				13.00	10	1	1	JPR	1	JPR		28.90	22	4.7	2.2	JPR		
	3.20			4.7	10				13.30	10	3.3						29.90	22	4.7	4.7	10		
	3.30	3.3							13.80	10	3.3	1	1				31.00	22	4.7	3.3	JPR	1	JPR
	3.50	1	1	2.2	4.7				14.10	4.7	4.7	4.7	JPR				32.00	22	10				
	3.80	3.3		1	1				14.30	10	3.3	1	JPR				33.50	22	10	2.2	4.7		
	4.00	1	1	1	JPR	1	JPR		14.70	10	4.7						34.48	22	10	3.3	10		
	4.40	2.2	2.2						15.20	10	4.7	1	1				36.10	22	4.7	4.7	JPR	4.7	JPR
	4.80	3.3	1	1	1				15.70	10	4.7	1	JPR				37.00	22	10	10	10		
	5.20	2.2	1	1	JPR	1	JPR	BEST	16.00	10	1	10	10				38.60	22	10	3.3	JPR	3.3	JPR
	5.70	4.7	1						16.60	10	3.3	3.3	JPR				40.00	22	10	4.7	JPR	3.3	JPR
	6.20	4.7	1	1	1				17.05	10	4.7	4.7	4.7				42.00	22	10	10	JPR		
	6.70	4.7	1	1	JPR				18.00	10	4.7	3.3	JPR				44.00	22	22				
	7.35	4.7	1	3.3	3.3				19.00	10	4.7	3.3	JPR	1	JPR		46.20	22	22	2.2	JPR		
	8.00	4.7	3.3						20.00	10	10						C_{EXT}	C1	C2	C3	C4	C5	C6
Plug in values at the right to calculate the combined capacitance of any combination.																								

#TURNS	Antenna Inductance Alone	Antenna Inductance +Cable		Range	Target Series C	Actual Series C	
1	22.3	23.7	µH	TOO LOW			
2	79.9	81.3	µH	JP1 IN			
3	167.4	168.8	µH	JP1 OUT+	35.5	25.0	nF
4	282.0	283.4	µH	JP1 OUT+	9.1		nF
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$$F = \frac{1}{2\pi\sqrt{LC}}$$

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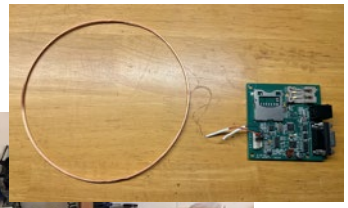
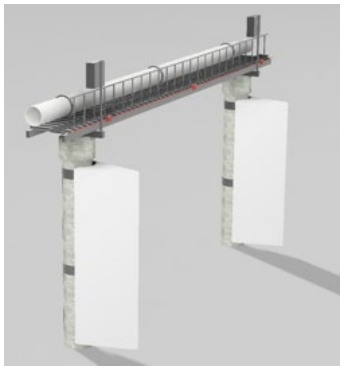
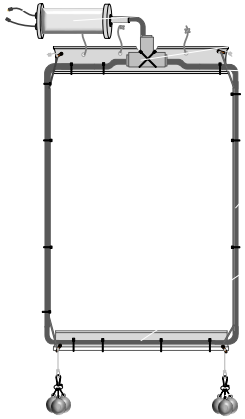
L – Inductance
C - Capacitance

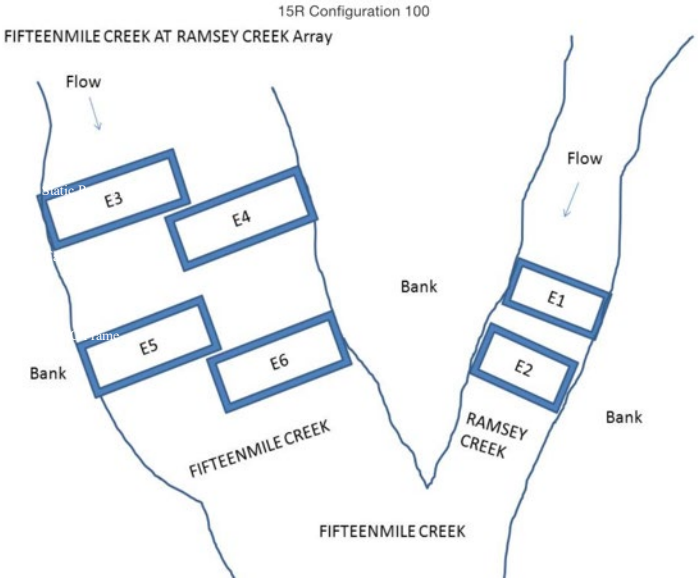
Antennas… it's just that easy



Antenna Install

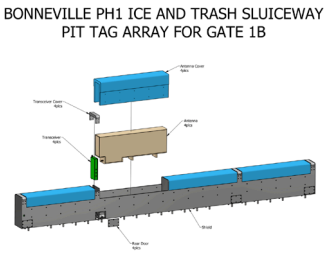






Site Selection

- Typically dictated by study design
- Consider power requirements
- Consider access for O&M



Placement

- Avoiding known external EMI – often requires testing
- Avoiding or mitigating for ferrous material in the antenna field
- Selecting the best antenna type for your location (pass-through, pass-by)

Anchoring

- Site specific, but there are many options
- Usually “driven” by antenna design

Questions?