PRELIMINARY INVESTIGATION OF A PASSIVE BASE VOLTAGE SAMPLING DEVICE USING A VOLTAGE DIVIDER AND A TRANSFORMER

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Purpose

I wish to see the results of this investigation – which was undertaken to evaluate an Idea that occurred to me when voltage sampling was first discussed for monitoring AM DA parameters in the early 1990s - in the public domain to encourage manufacturers to explore the described concepts for the possible development of manufactured products.

Why Voltage Sampling?

New FCC rules to allow DA proofing using internal array measurements and method of moments modeling to establish operating parameters became effective today – ushering in a new era of greatly reduced engineering costs for AM stations that employ DAs. The new section 73.151(c) allows voltage sampling for antenna monitors when series-fed towers are over 105 degrees in electrical height. No voltage sampling devices are presently on the market, however.

Voltage sampling will be necessary for stations having series-fed towers between 120 and 190 degrees in height that do not have identical cross-sectional structures to avail themselves of the new rules, as they do not qualify for either loop or base current sampling. It will also be an attractive option for all systems having series-fed towers greater than 105 degrees in electrical height with users who prefer sampling devices within ATU enclosures rather than tower-mounted sampling loops. Although not contemplated by the present rules, I believe that further study may prove voltage sampling to be useful for monitoring skirt-fed aka "folded unipole" towers in DA systems.

Voltage Divider Limitations for Sampling

The fact that several volts must be developed across the 50 ohm input of an antenna monitor limits the use of a simple voltage divider for monitoring tower base voltage to towers with very high voltages if the loading effects of the impedance presented across the tower base by the sampling device are to be minimized.

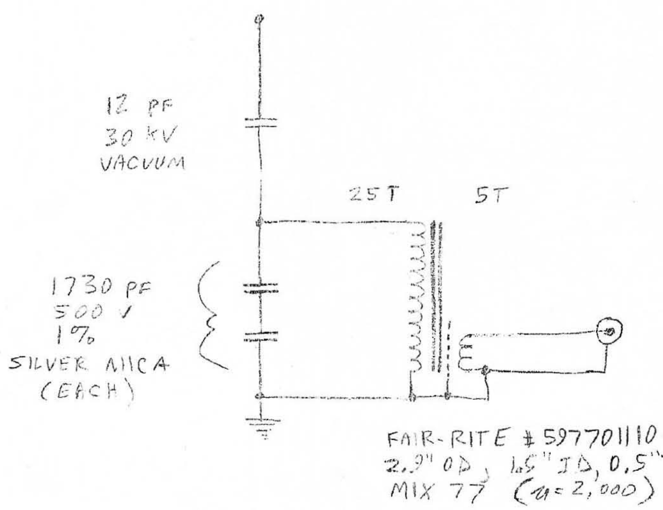
Voltage Transformer Limitations for Sampling

A voltage transformer dual of the type of current transformer that has been in common use for monitoring tower base currents for over 40 years – as manufactured by Bauer, Delta Electronics, Geleco and Phasetek – would be ideal, as a transformer steps impedance by the square of the voltage transformation ratio. A transformer to step a tower base voltage of 1,000 volts down to 10 volts, for instance, would have an impedance ratio of 100 X 100 = 10,000 and the impedance of its primary with its secondary loaded by the 50 ohm antenna monitor input would be an inconsequential 500,000 ohms across the tower base [with Ideal transformer assumptions]. The tower base voltage would have to appear across the "gap" of the multi-turn ferrite toroid core's primary winding, though, instead of the antenna monitor level voltage that appears across the multi-turn secondary of a current transformer. As tower base voltages can be several thousand volts, this is not a practical option.

A Combined Passive Approach

The concept that is explored herein uses a transformer with a voltage ratio of 5:1 and an impedance ratio of 25:1 to establish an intermediate point, located between a voltage divider consisting of two series reactances and the transformer primary, where an RF voltage in the range of 10 to 100 volts would produce an antenna monitor input [50 ohm] voltage of 2 to 20 volts. It is believed that reactive components can be selected to provide an intermediate voltage within this range without significant loading effects across the tower base, given the nominal 1250 ohm resistance presented by the transformer primary.

The reactances can be either inductive or capacitive -- or a combination of the two. The circuit that has been tested uses a capacitive voltage divider that would have the loading effect of a 12 pF capacitor placed across a tower base. Tests show that it would provide an output voltage in the range of 2 to 20 volts, into a 50 ohm load, for a tower base voltage in the approximate range of 850 to 8,500 volts throughout the AM band (with sufficient voltage rating for the 12 pF capacitor).



RF VOLTAGE SAMPLER X-1

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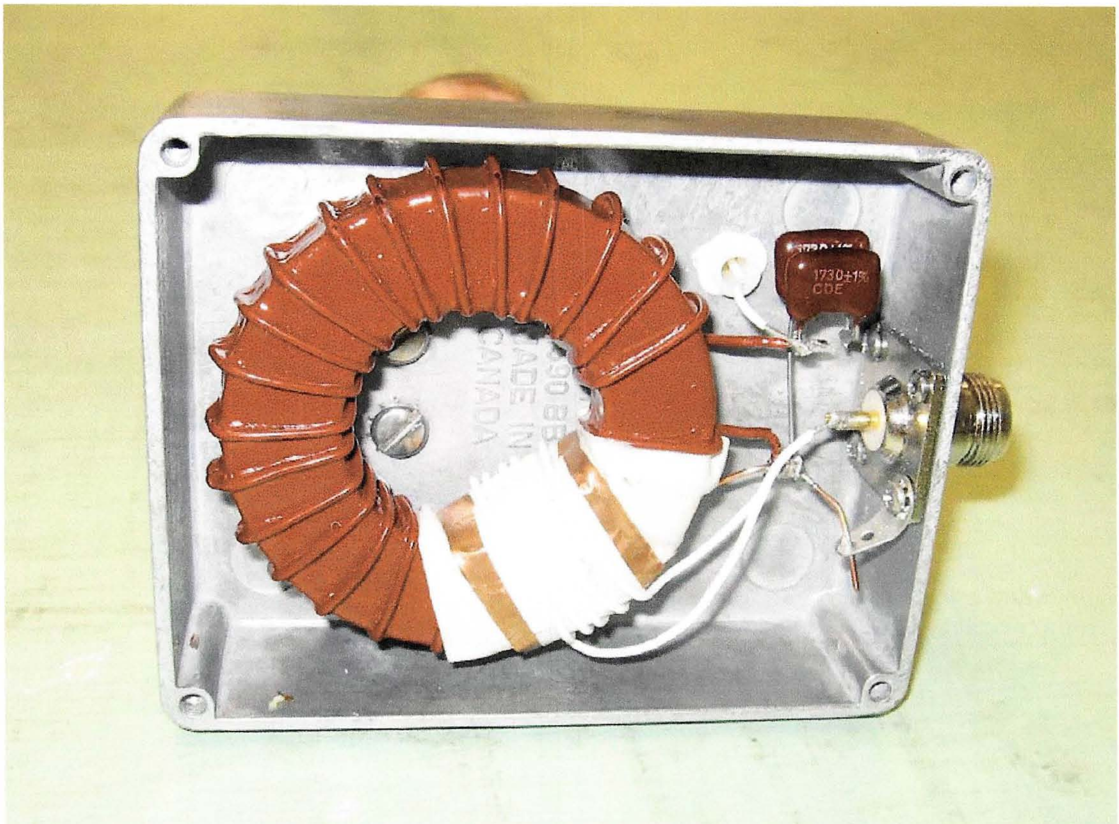
PROTOTYPE VOLTAGE SAMPLER S/N X-1



PROTOTYPE VOLTAGE SAMPLER S/N X-1

The ferrite core has a primary winding with 25 turns of 16 gauge Formvar transformer wire. Three coats of Glyptal 1201 Red Enamel were applied over the core and primary winding - and baked on. The secondary winding consists of 5 turns of 20 gauge teflon insulated wire wound over a layer of glass cloth insulating tape, which surrounds a grounded shielding layer of copper foil. The shield has a gap along the outside of the toroid to avoid shorting the magnetic circuit and has a layer of glass cloth insulating tape underneath it.

An autotransformer, with a tap five turns above the ground connection instead of a separate secondary winding, may be satisfactory and offer advantages from a manufacturing standpoint. Perhaps one should be tested.

The transformer and silvered mica capacitors are inside a 3.6 X 4.6 X 1.3 inch cast aluminum box. The transformer is held in place with RTV 162 electrical grade silicone adhesive and insulating spacers.

WESTBERG CIRCUIT ANALYSIS PROGRAM

FILE NAME = vsx1.cir

I	1000.0000	0	1	.0000	.0000	.0000	
R	1.0000	1	0	.0000	.0000	.0000	
R	1.0000	1	2	.0000	.0000	.0000	
C	.0000	2	3	.0000	.0000	.0000	(0.000012 or 12 pF)
C	.0009	3	0	.0000	.0000	.0000	(0.000865 or 865 pF)
R	960.0000	3	4	.0000	.0000	.0000	
R	240.0000	4	0	.0000	.0000	.0000	
EX	.0000	0	0	.0000	.0000	.0000	

FREQ = .540

NODE	VOLT MAG	VOLT PHASE
1	999.9998	-.0023
2	999.9997	-.0046
3	13.1761	15.6406
4	2.6352	15.6405

				BRANCH VOLTAGE		BRANCH CURRENT		FROM NODE IMPEDANCE		TO NODE IMPEDANCE		
				MAG	PHASE	MAG	PHASE	RESISTANCE	REACTANCE	RESISTANCE	REACTANCE	VSWR
R	1-	0	1.000	1000.00	-.002	1000.00	-.002	1.00	.00	.00	.00	
R	1-	2	1.000	.04	89.826	.04	89.826	74.54	-24876.36	73.54	-24876.36	
C	2-	3	.000	987.32	-.211	.04	89.789	89.53	-24876.26	89.53	-315.31	
C	3-	0	.001	13.18	15.641	.04	105.641	.00	-340.73	.00	.00	
R	3-	4	960.000	10.54	15.641	.01	15.641	1200.00	.00	240.00	.00	
R	4-	0	240.000	2.64	15.641	.01	15.641	240.00	.00	.00	.00	

FREQ = 1.000

NODE	VOLT MAG	VOLT PHASE
1	999.9999	-.0043
2	999.9997	-.0085
3	13.5292	8.5912
4	2.7058	8.5912

				BRANCH VOLTAGE		BRANCH CURRENT		FROM NODE IMPEDANCE		TO NODE IMPEDANCE		
				MAG	PHASE	MAG	PHASE	RESISTANCE	REACTANCE	RESISTANCE	REACTANCE	VSWR
R	1-	0	1.000	1000.00	-.004	1000.00	-.004	1.00	.00	.00	.00	
R	1-	2	1.000	.07	89.859	.07	89.859	32.09	-13442.67	31.09	-13442.67	
C	2-	3	.000	986.62	-.126	.07	89.874	27.56	-13442.68	27.56	-179.77	
C	3-	0	.001	13.53	8.591	.07	98.591	.00	-183.99	.00	.00	
R	3-	4	960.000	10.82	8.591	.01	8.591	1200.00	.00	240.00	.00	
R	4-	0	240.000	2.71	8.591	.01	8.591	240.00	.00	.00	.00	

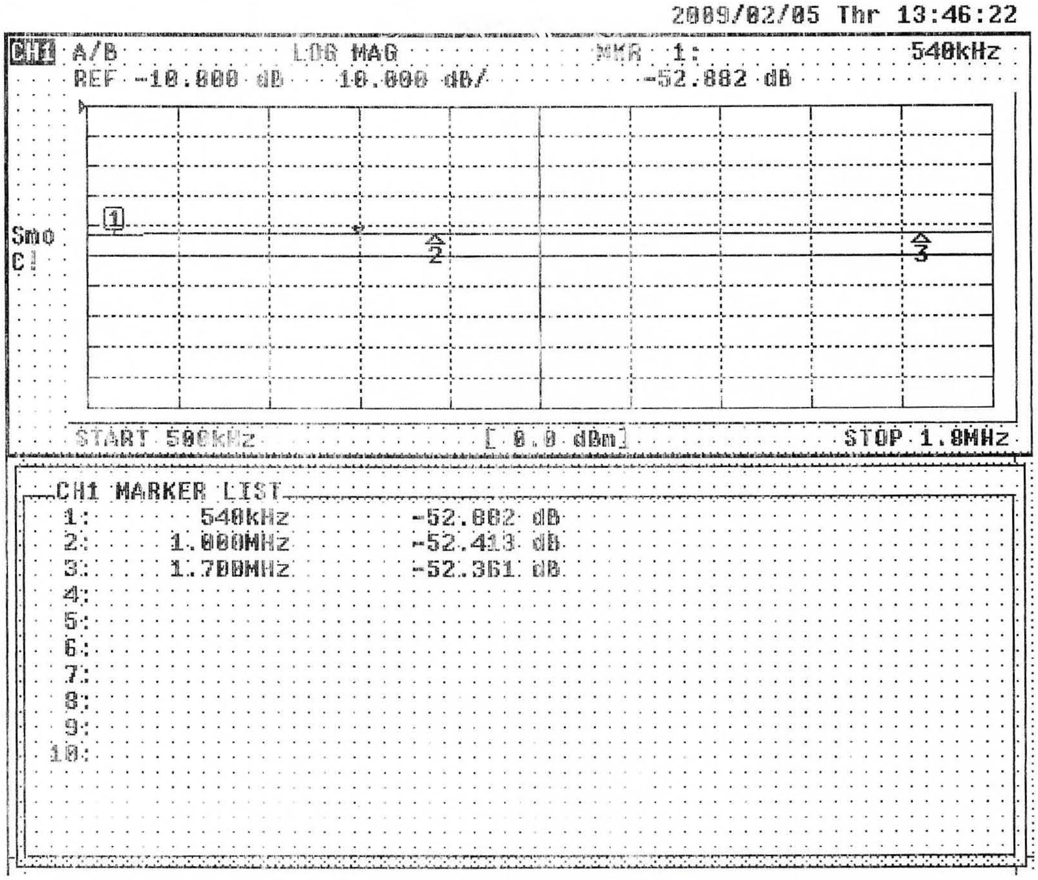
FREQ = 1.700

NODE	VOLT MAG	VOLT PHASE
1	999.9999	-.0072
2	999.9996	-.0145
3	13.6292	5.0691
4	2.7258	5.0691

				BRANCH VOLTAGE		BRANCH CURRENT		FROM NODE IMPEDANCE		TO NODE IMPEDANCE		
				MAG	PHASE	MAG	PHASE	RESISTANCE	REACTANCE	RESISTANCE	REACTANCE	VSWR
R	1-	0	1.000	1000.00	-.007	1000.00	-.007	1.00	.00	.00	.00	
R	1-	2	1.000	.13	89.889	.13	89.889	14.27	-7909.06	13.27	-7909.06	
C	2-	3	.000	986.42	-.085	.13	89.915	9.68	-7909.07	9.68	-107.36	
C	3-	0	.001	13.63	5.069	.13	95.069	.00	-108.23	.00	.00	
R	3-	4	960.000	10.90	5.069	.01	5.069	1200.00	.00	240.00	.00	
R	4-	0	240.000	2.73	5.069	.01	5.069	240.00	.00	.00	.00	

WCAP NODAL ANALYSIS OF PROTOTYPE X-1

(Uses resistive voltage divider to simulate ideal transformer response)

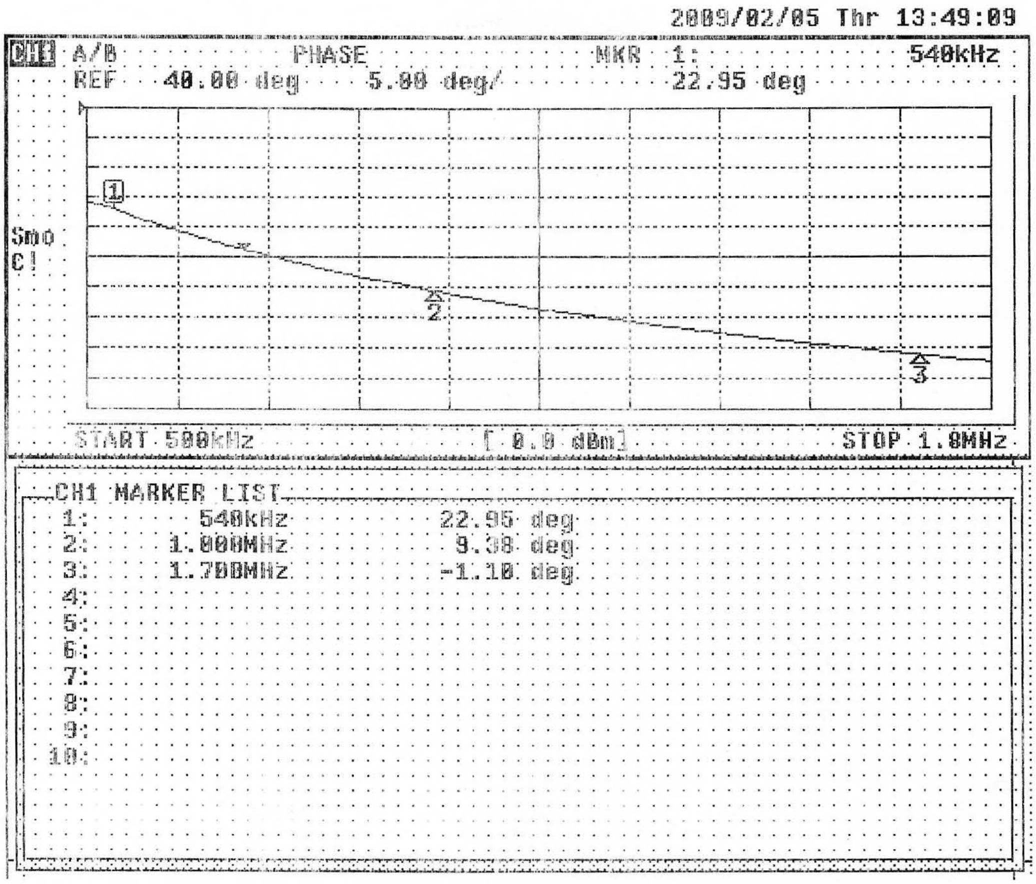


PROTOTYPE X-1 OUTPUT/INPUT RESPONSE
MEASURED WITH VECTOR NETWORK ANALYZER

Frequency (KHz)	WCAP Calculated Output for 1 KV Input (Volts)	Output/Input (dB)	Measured (dB)	Difference (dB)
540	2.64	-51.6	-52.9	1.3
1000	2.71	-51.3	-52.4	1.1
1700	2.73	-51.3	-52.4	1.1

The noted differences are thought to be principally due to stray capacitance within the box. A larger box might be desirable.

It is expected that devices can be built to have matched characteristics for single frequency use.



PROTOTYPE X-1 OUTPUT/INPUT PHASE
MEASURED WITH VECTOR NETWORK ANALYZER

Frequency (KHz)	WCAP Calculated Output/Input Phase (Degrees)	Measured Output/Input Phase (Degrees)	Difference (Degrees)
540	15.6	23.0	7.4
1000	8.6	9.4	0.8
1700	5.1	-1.1	4.0

The noted differences are thought to be principally due to leakage inductance within the transformer.

It is expected that devices can be built to have matched characteristics for single frequency use.

For Further Investigation

Several things have come to mind as needing further investigation before this design is considered ready for use in the field:

1. The thermal stability, which involves both the respective temperature coefficients of the vacuum and mica capacitors and the permeability-vs-temperature characteristics of the ferrite core. [Published ratings suggest both should be acceptable, but I'm no expert on ferrite materials.] This may be tested in a temperature controlled chamber.

2. The ability of the toroid core to handle flux densities over the design operating primary voltage range at AM band frequencies. This may be tested by stepping up the output of a laboratory amplifier to a high impedance, connecting the sampler across the high impedance node, and measuring the response and phase at different voltage levels to evaluate linearity and phase stability.

3. The potential for antenna monitor damage with lightning or static discharges that cause an internal vacuum capacitor flashover. It is common to see such damage to toroid sampling devices but antenna monitor damage is relatively rare.

4. Whether an inductor might be used instead of the vacuum capacitor without unpredictable performance due to stray coupling to its windings. Perhaps a completely shielded inductor would be required. It is noted that an inductor may offer more immunity to antenna monitor damage due to lightning or static discharges than a capacitor.

5. Whether the performance will be adversely impacted by the range of load characteristics presented by normal variations in antenna monitor inputs and sampling lines.

Conclusion

If additional studies show that a design along the lines of the described concept can serve for voltage sampling in the antenna monitor systems of AM DA arrays, as it appears from the design and test data presented herein that it can, I would like to see it tried. The information contained herein may be used by any and all who desire to look into this concept further. I have no commercial interest in it and I consider nothing presented herein proprietary. My interest is in seeing that the best technology possible is available for use by my clients.