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green, yellow, and red regions. You can easily validate these results using numerical electromagnetic code such as *EZNEC*.[3]

The exact electric near fields at three specific places inside the small loop are $E_{0,0}$ at the loop center, E_{gap} across the gap-capacitor, and $E = 0$ on the loop wire opposite the gap. The electric field at the gap-capacitor is easy to find from the rms capacitor voltage.

$$V_{cap} = \sqrt{X_C Q_L P} \qquad \text{[Eq 6]}$$

where:
X_C is the capacitor reactance at resonance,
Q_L is the loaded Q of the loop, and
P is the power radiated by the loop. Then Equation 7 gives the desired field.

$$E_{gap} = \frac{V_{gap}}{g} \qquad \text{[Eq 7]}$$

where g is the gap dimension in meters and E_{gap} is in V/m.

The important result here is that there can be an enormous electric field near the small loop that originates from the slight departure from a constant loop current as seen in Equation 1. The response is like that of an *electric* dipole oriented across the plane of the loop (along the field lines in Figure 1), while the expected far field response is like that of a *magnetic* dipole oriented through the axis of the loop (into the page in Figure 1). Practically, this means that as you get close to the source, the normally expected loop null will become filled in by the near field electric dipole response. That combined response may skew the expected loop response while direction finding or searching for RFI. —*73, Kazimierz "Kai" Siwiak, KE4PT, 10988 NW 14 St, Coral Springs, FL 33071*; **k.siwiak@ieee.org**

Uninterruptible Power Supply Safety Concerns (May 2014)

I have one more comment for the technical correspondence about uninterruptible power supply (UPS) safety. If you're not sure whether your UPS battery is connected to one side of the ac line, you can still use it by placing an appropriately (power) rated ac isolation transformer between the ac line source and the UPS. I currently use three UPS units that have the ac line connected directly to the battery. I use two commercial isolation transformers and a double isolation transformer made up from two 24 V ac, 5 A transformers. Do this and it's harder to get bitten. Isolation transformers are also good ideas for old hot-chassis tube equipment. — *73, Curt Law, AL7LQ, PO Box 42, Kodiak, AK 99615;* **curt@kadiak.org**

Simulation of the Low Noise Oscillator from *Solid State Design for the Radio Amateur*

An article by Colin Horrabin, G3SBI, about part of the HF7070 receiver in the Nov/Dec 2014 issue of *QEX* retriggered my interest in variable frequency oscillators and variable crystal oscillators.[4] That led me to perform some simulation analysis of a number of older published designs, using Ansoft *Serenade* modern circuit simulation software.

One oscillator that especially caught my attention was described in ARRL's *Solid State Design for the Radio Amateur*.[5] This oscillator is a very interesting design. It was designed for low-noise performance by Linley Gumm, K7HFD. As published, this is a 10 MHz oscillator. Because it is current limiting, the phase noise is quite good, but the large signal operation makes a lot of harmonics. This oscillator needs a lot of filtering.

My simulation agrees with the measured published data (see Figure 3). The accuracy, given the lack of software, along with test equipment that in 1977 wasn't what we have today, is impressive. I find that Wes Hayward, W7ZOI, is one of the few individuals whose publications are correct.

The use of FETs, rather than bipolar transistors, would not give much improvement in this circuit, because its output power would be much less, and therefore the phase noise or signal to noise ratio would be worse.

Needless to say, a buffer amplifier is needed for isolation, and the predicted far off phase noise gets worse. At higher frequencies it becomes difficult to build the ferrite-core-based resonator and its windings, and maintain the needed coupling.

To transform this circuit to 60 MHz, even with the same Q, shows a worse phase noise in simulation. This is because the input impedance at higher frequencies gets lower and the matching of the transistor has to be changed. Here modern simulation tools shine!

There was a similar design in *Communications Circuits: Analysis and Design* by Clarke and Hess (**samanezehn.com/ketab2.pdf**). There is also a more detailed noise analysis in *Design of Modern Microwave Oscillators for Wireless Applications*, by Rohde, Poddar, and Boeck. Do a Google search on the title for more information. Also go to **https://www.google.com/?gws_rd=ss1#q=Ulrich+Rohde+dissertation** for additional reference material.— *73, Ulrich L. Rohde, N1UL, 990 Cape Marco Dr, Marco Island, FL 34145*; **ka2weu@aol.com**

■ The designer of this oscillator was Linley Gumm, K7HFD, a colleague when I worked at Tektronix. Doug DeMaw, W1FB (SK), and I included his circuit, including noise measurement data, in *Solid State Design for the Radio Amateur* because it exemplified several design points we wanted to make. The design was not just an exercise, however. Linley actually measured the noise performance of his oscillator and it was very good, especially for the mid 1970s time frame. Indeed, it holds up well today with measured noise at –156 dBc/Hz at 10 kHz spacing. Additional data and discussion are presented in *Experimental Methods in RF Design*.[6]

One of the reasons this design is so good is that tank Q is high, a vital part of low noise oscillator design. Also, stored tank energy is high. The voltage in the tank is about 60 or 80 V_{P-P}. Unfortunately, the high tank RF voltage means that you cannot casually connect varactor diodes in place of the traditional variable tuning capacitor that was used. Hence, the circuit is not a good basis for a synthesizer. This circuit is easily simulated with *SPICE*, providing operating levels, waveforms, and harmonic content, but no phase noise data. A harmonic balance simulator is needed for noise. — *73, Wes Hayward, W7ZOI, 7700 SW Danielle Ave, Beaverton, OR 97008*; **w7zoi@arrl.net**

■ I'm glad that the 1977 measurement data was accurate. It was made with a rather brute force method using a narrow (1 kHz or 3 kHz) 10 MHz center crystal filter with narrow skirts. The oscillator was tuned into the passband to measure its power, and then tuned to the side so only its phase noise passed through the filter. The amplitude ratio was measured with a spectrum analyzer, which could do so unambiguously because the carrier was well attenuated by the filter.

I can think of three reasons why this oscil-

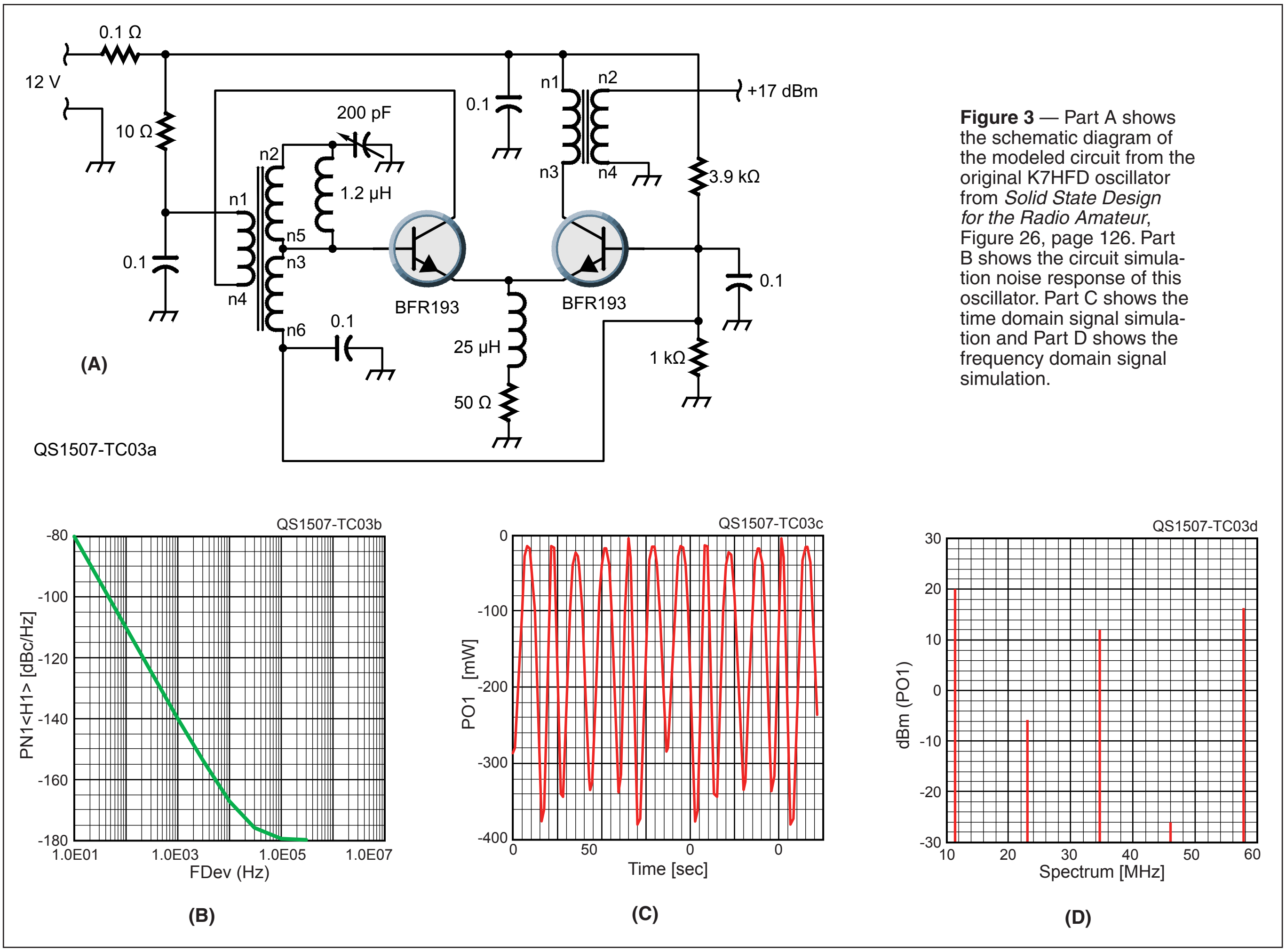

Figure 3 — Part A shows the schematic diagram of the modeled circuit from the original K7HFD oscillator from *Solid State Design for the Radio Amateur*, Figure 26, page 126. Part B shows the circuit simulation noise response of this oscillator. Part C shows the time domain signal simulation and Part D shows the frequency domain signal simulation.

lator exhibits low phase noise. First is that the LC resonator is loaded by the transistors only when the resonator voltage swings through zero. The resonator thus operates very near its unloaded *Q* for the rest of the cycle. In the Leason model, using an amplifier matched to the resonator, the optimum loaded *Q* is ½ the unloaded *Q*. The upshot is that, at least in theory, the flank of the phase noise curve is thus pushed to the left by an octave.

Second, the oscillator's amplifier is active only for a very short period at each zero crossing. It sits in a current limited condition for the rest of the cycle, and thus contributes little noise then. Anything that lengthens the period that the amplifier is active will increase the noise.

Third, as described on page 33 of *The Design of Low Noise Oscillators* by Ali Hajimiri and Thomas H. Lee, the impulses given by the amplifier to the resonator are timed and provided in such a way that if their magnitude is noisy, this is reflected in the amplitude of the resonator's voltage and not its phase. How and when the impulse is provided to the resonator is an important concept. It is one of those ideas that is obvious when pointed out, but often not before.

[I think this approach is misleading. I don't believe anyone has been able to recalculate a built oscillator and correlate the measurements. — *N1UL*]

I designed the oscillator with points one and two in mind. That it also met Hajimiri's criteria for low noise was just serendipitous. By the way, Hajimiri and Lee's book is an excellent reference.[7] — *73, Linley Gumm, K7HFD, 19505 SW Southview Pl, Beaverton, OR 97078*; **k7hfd@arrl.net**

Notes

[1] Tom Thompson, W0IVJ, "Locating Interference at HF," *QST*, Nov 2014, pp 33 – 39.

[2] K. Siwiak and Y. Bahreini, *Radiowave Propagation and Antennas for Personal Communications, Third Edition*, Artech House, Norwood MA: 2007, Chapter 11.

[3] Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[4] Colin Horrabin, G3SBI, "The Development of the Low Phase Noise Double Tank Oscillator," *QEX* Nov/Dec 2014, pp 35 – 43.

[5] Wes Hayward, W7ZOI, and Doug DeMaw, W1FB, *Solid State Design for the Radio Amateur*, Chapter 6, Advanced Receiver Concepts, 1977 and 2nd printing 1986, pp 126 – 127.

[6] Wes Hayward, W7ZOI, Rick Campbell, KK7B, and Bob Larkin, W7PUA, *Experimental Methods in RF Design*, ARRL, 2003-2009, pp 4.12 – 4.13.

[7] Ali Hajimiri and Thomas Lee, *The Design of Low Noise Oscillators*, 1999, Kluwer Academic Publishers, Norwell, Mass. Available from **www.amazon.com**.

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