A Vehicular RDF Set using Switched Parasitic Elements

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Radio Direction Finding (RDF) from a mobile platform has seen service for well over half a century. Antenna size limitations restrict us to just a few techniques, even at VHF. "Real Aperture" antennas (such as a Yagi) are uncomfortably big, and difficult to use. Small antennas can give accurate bearings if we employ electronic tricks such as lobe switching or a doppler-spun array. The ideal mobile RDF set would be simple, easily added to an existing mobile installation, and should give rapid and unambiguous bearing and signal strength readouts to the driver/operator. With LEFT/RIGHT indication only, the determination of TO/FROM requires an extra mental effort, especially in a vehicle. Thus "unambiguous" bearing requires both a LEFT/RIGHT and a TO/FROM indication.

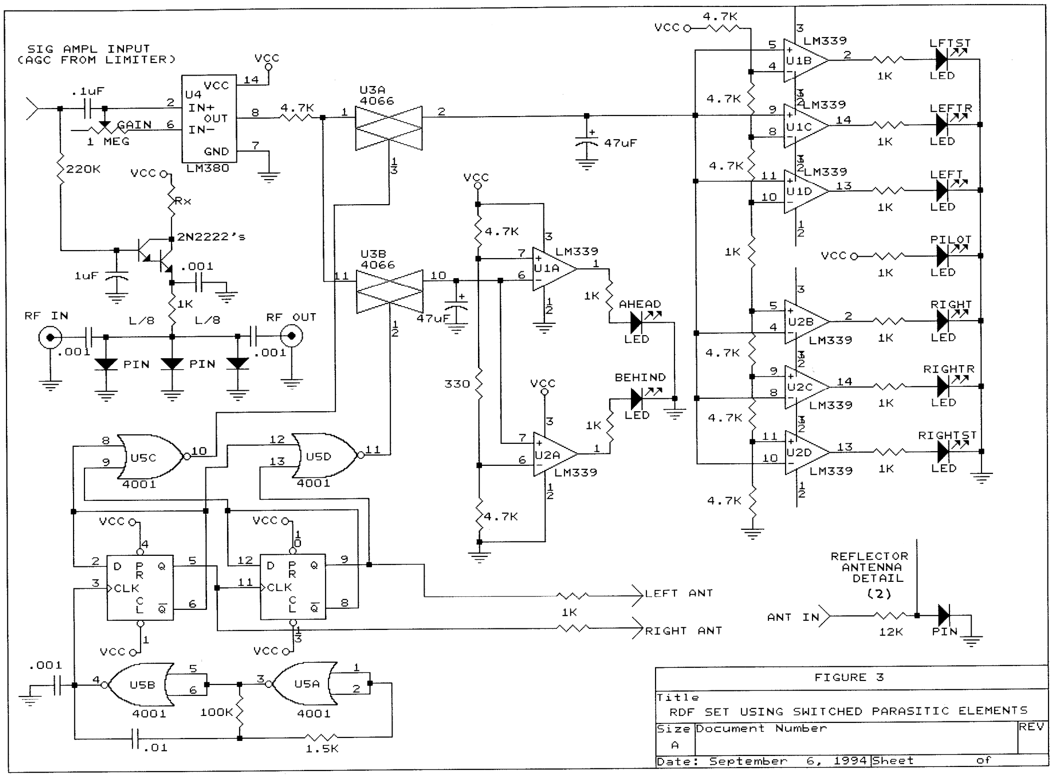
This approach to an antenna lobe switched RDF Set is suggested as an alternative to the more common in-line lobe switchers (L-Tronics Little L-Per, etc.) which require special antennas. A pair of parasitic reflector elements on magnetic mounts (each modified with a PIN diode switch to ground) are symmetrically placed behind the existing mobile antenna and are driven by the RDF set. In addition to the standard LEFT/RIGHT indication, a TO/FROM signal is available. The only RF connection is to the existing mobile quarter-wave antenna.

This is how it works: When the LEFT reflector PIN diode is energized, the reflector appears and causes the driven element (mobile antenna) to develop some gain to the RIGHT, and visa versa. Note that an open PIN switch allows no RF reflector current to flow, and the parasitic element seems to "disappear". By symmetry, the LEFT and RIGHT antenna patterns have two equal gain points: ahead (front) and behind (rear). Switching between these two patterns gives an amplitude difference signal proportional to the angle from either front or rear (see FIGURE 1) which can be used for a LEFT/RIGHT display. The actual gain difference is small, so the angular sensitivity can be increased by amplification of the difference signal. In radar, this use of two lobes is called "monopulse" or "beam sharpening". Now, consider another case. If neither reflector is energized, the pattern is omni-directional and if both are energized, there is some symmetrical forward gain. The equal gain points of these two patterns are to the left and right of the vehicle. Switching between these two patterns gives a difference signal indicating source ahead or behind (see FIGURE 2). To get the exact difference signal, one should really subtract min from max. However, if the signal is AC coupled, just one side need be sampled (the other is of equal amplitude but reversed in sign). Combining both of the above switching signals is easily done. A two-stage binary counter generates the necessary waveforms. Sampling times are decoded from the counters using two NOR gates. As in the separate cases above, the now four state output signal is AC coupled to the amplifier. The two CMOS static switches on the amplifier output provide integrated simultaneous LEFT/RIGHT and TO/FROM analog signals. If the LEFT/RIGHT and TO/FROM amplitude averages are nearly the same, the single sided sampling gives a good approximation to the actual difference value. Switching frequency is largely arbitrary, but 200/100 Hz is a reasonable compromise value.

Figure 3 is the schematic of the DF set. Series 4000 CMOS permits operation at 12V rather than 5V. A wide dynamic range frequency synthesized AM receiver is ideal for this application, but these are difficult to come by, particularly for vehicular service. Adapting an FM receiver (no AGC) requires receiver surgery and an external electronic attenuator. When carefully built, a PIN diode attenuator can approach a range of 50 dB, but does require an external attenuator when near the RF source. The attenuator consists of three PIN diodes separated by two 1/8 wavelength pieces of miniature coax, AC coupled to coax adapters, and driven by an NPN darlington pair. Metering the DC attenuator current gives a signal strength reading, but select Rx (around 10K) to limit meter current. When the attenuator is out of range the input goes way up! The input circuit shown is used with a Kenwood 7800, connecting the DF set input to the limiter stage which drives the LED signal display. The LM380 audio amplifier input is AC coupled, and has a DC output level of Vcc/2 (or 6V). Angle sensitivity is controlled by amplifier gain. Samples of the amplifier signal output are sent to holding capacitors using a pair of NOR gated 4016 CMOS static switch stages. Display LED drivers are the LM339 voltage comparators. The parasitic antenna elements are switched with PIN diodes to ground using the two counter stage outputs and resistors for RF isolation. One milliampere is enough current for clean PIN switching. A square wave of approximately 400 Hz drives the first counter clock input, coming from a two stage relaxation oscillator made from the remaining NOR gates. Reflector antenna elements are about 5% longer than the driven element, and element placement is not critical. Spacing the reflectors 0.15 wavelength behind the driven element, separated symmetrically about 0.1 wavelength apart works well. At two meters, this translates to 20 inch whips placed 12 inches behind and 4 inches on either side of centerline (in a 12" x 8" isosceles triangle).

A good display is essential for mobile operation. Dual analog meters could be used, but an LED display can be used at night, and mounted in front of the driver for one-man heads-up operation. The display chosen for LEFT/RIGHT is a seven LED horizontal line "twin thermometer" with three lights for each direction (leftest, lefter, left, pilot, right, righter and rightest in order, left to right). TO/FROM has only two LED's, one above and one below the center pilot (green) LED.

It is a good idea to filter and zener spike limit the 12v power, because CMOS is very sensitive to high voltage transients. Lobe switchers do not require an RF carrier (as does the doppler spun array), and will handily DF on an SSB or a noise emitter. Figure 4 shows a test target generator. Rather than try to swamp down an HT for system calibration, this little oscillator does a nice job. Any NPN HF silicon transistor will work in this circuit (even a 2N2222). The RF choke is not a critical component. If no Z-144 can be found, just close-wrap a 100k 1w carbon resistor with #20 wire. Pick any 3 to 10 MHz crystal having a harmonic on an unused channel. The series tuning capacitor moves the harmonic frequency up to 100 kHz depending on the crystal. This article is not intended as a "cookbook" or wire-by-number project, but just to suggest a simple and elegant way of hunting the bunny. Hams with a technical bent can cobble together a killer DF set. This one has found many a stuck transmitter since first built in 1980.


SIG AMPL INPUT
(AGC FROM LIMITER)
.1uF
GAIN
1 MEG
220K
U4
LM380
VCC
IN+
IN−
OUT
GND
4.7K
U3A
4066
U3B
4066
47uF
Rx
2N2222's
1uF
.001
1K
RF IN
RF OUT
L/8
PIN
330
LM339
U1A
U2A
AHEAD
BEHIND
LED
U1B
U1C
U1D
U2B
U2C
U2D
LFTST
LEFTR
LEFT
PILOT
RIGHT
RIGHTR
RIGHTST
U5C
U5D
4001
U5B
U5A
100K
.01
1.5K
D
CLK
LEFT ANT
RIGHT ANT
REFLECTOR
ANTENNA
DETAIL
(2)
ANT IN
12K
FIGURE 3
Title
RDF SET USING SWITCHED PARASITIC ELEMENTS
Size
A
Document Number
REV
Date: September 6, 1994
Sheet
of