A Novel foxhunt system

by

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For many years now both myself and fellow amateur John Wood have enjoyed the competition of 'T' hunting.

John Wood (left) and Dave with ARCON foxhunt trophy

Known as 'Foxhunting' here in the UK, our local **A**mateur **R**adio **C**lub **O**f **N**ottingham (**ARCON**) competition is run on 2 metres FM and draws about 8 to 10 teams once a month throughout the summer season.
There is a variety of equipment used, ranging from complex Doppler systems to the simple HB9CV and handie talkie.
Having been hovering in the championship top three for a couple of years we decided to *up* our commitment and try to win the trophy.
We had already been instrumental in introducing the first Doppler system into the club's hunts based on the June 1981 design in 73's Magazine by W7BEP.
Whilst the Doppler hunter worked well and was pretty sensitive, it seemed lacking in selectivity when hunting in built up areas. We conducted some tests and found that indeed the multi-path environment was the ideal place to hide to confuse a Doppler system. The Doppler would just lock on to the strongest signal whether direct or reflected!

This was hopeless, as at that time industrial estates and heavily built up areas were frequently favoured by the fox.
What we needed was a system that would be able to differentiate between all these different signals. This sounded like a job for a DSP and the sort of complicated algorithms that were beyond the scope of our experience.
As the club rules say 'No commercial Hi-Tech equipment allowed' that meant that we couldn't use any 'off the shelf' DF equipment or military surplus hardware either.
We needed an effective, simple approach.

The Idea.

John had been reading about wartime submarine hunters, and was impressed by their simple rotating loop and c.r.t. display systems. These quickly located the submarine as it popped up to make it's clandestine transmission. The direction and signal strength were displayed on a c.r.t. vector style display.
This seemed like a good idea as unlike the Doppler, the display would show all of the signals arriving at the vehicle which is exactly what we wanted!
All we had to do was re-develop the system with modern electronics and some mechanical genius.

From our experiences with the Doppler system we knew that 1/4 wave antennas were not sensitive enough for this application. There were a few times when we couldn't hear the 'fox' from the start, (very frustrating having to just drive from high spot to high spot hoping for a signal)! By the same reckoning loops were out too, what we needed was lots of gain and directivity….a beam!.

The system outline

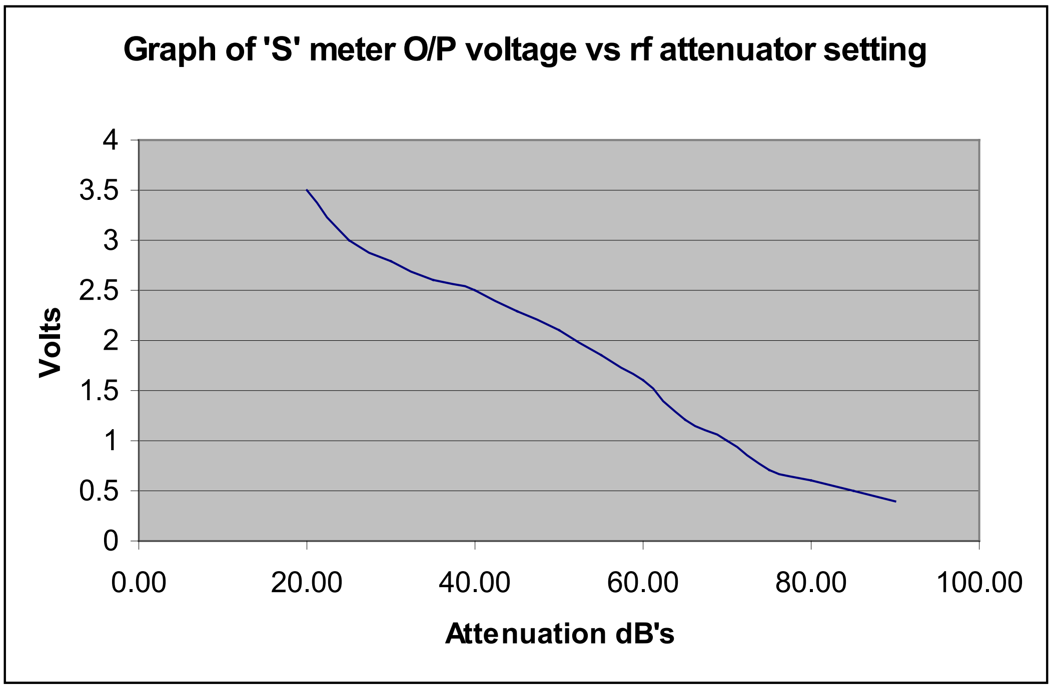
1). Basically the system should rotate a beam antenna on the top of the car connected to the vehicle's 2 metre radio.
2). Take the output of the 'S' meter circuit from that radio and display it on an LCD or c.r.t readout device.
3). Somehow synchronise a circular timebase to the rotation of the antenna such that the signal strength information is swept around the screen.
4). Fit a compass ring around the diameter of the c.r.t. to show the bearing in degrees.
5). Find a foolproof way of transferring that bearing to the map!

Hey, simple!

We carried out tests on our 2 metre amateur band radios and found that they were very lacking in the 'S' meter department. My Yaesu FT290 had less than 9dB's useable scale!
Visiting various radio rallies and talking with local radio Hams, we discovered the ideal radio, a Private Mobile Radio (PMR) set, the Pye M2000.

This transceiver was used for commercial traffic and operated on 'System 3' which was a communication protocol whereby the transceiver searched around for the strongest basestation and then established a link through that location.
The I.F. used a TCA440/1 and a transistor output stage to give a pretty linear field strength indication of 0 - 3.5 volts, (no signal to fully quieting).
This voltage is used by the circuitry that determines the quality of the link.
John fed a high input impedance buffer from this point and routed it's output to a socket on the back of the radio.
As there are no rf gain controls on the M2000 there is always the same relationship between signal strength and this buffered output. (ideal for estimating the 'distance to fox')

FIG 2



We now had our signal strength to dc voltage generator, the next task was devising some way of displaying this information.

We needed a compact display that could run off the car battery. A storage oscilloscope would have been ideal, but the cost, and mains power requirements of the ones available on the junk market were prohibitive!
It was then that we were offered a 12 Volt VDU by one of the amateurs at the local radio club. With enthusiasm renewed, I collected it the next day and set to work stripping out all the unnecessary bits. After quite a short time I had the EHT generator running by substituting a ferrite ring inductor for the horizontal scan coils.
The set seemed happy to have it's vertical coils disconnected too, so now I had both sets of coils available to be driven externally.

Next I checked the phosphor, we needed a long persistence if we were to get a meaningful display from a slowly rotating antenna. With the brightness full up there was just about enough persistence to be workable, as long as the display area was kept small.

I designed some X and Y deflection amplifiers around L165 IC's, connecting them in bridge format to drive the scan coils, but ran immediately into trouble. The scan coils were too low an impedance to be driven by the amplifiers. Undeterred, (as this was the only display available), I rewound the scan coils with thinner wire and could then move the trace over a 2 inch area of the tube quite quickly without distortion.

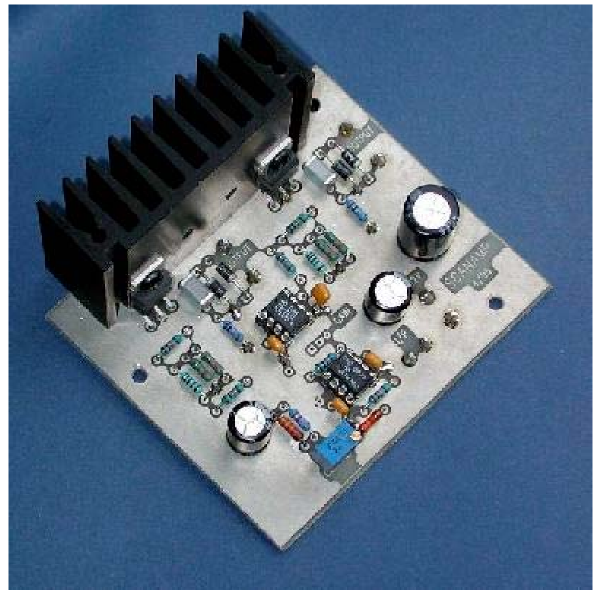


Fig 3 picture of scan amplifiers.

Whilst I was struggling with the display John was developing the rotator. We wanted a very sturdy system that could rotate a small beam whilst driving at up to 70 miles per hour.
Out of his bottomless junk box came a automobile windscreen wiper motor, a couple of bicycle chain wheels and a length of chain.
He made the main antenna bearing from a Austin Mini front wheel hub and bolted the whole assembly to a couple of surplus ladder racks.
The 12 volt motor and chain wheels provide a 1:1 drive and rotate the antenna at 60 r.p.m. The stub mast is hollow, allowing the antenna coax to pass down it's center to our rotating joint.

Having scoured the internet for 'noise free' rotating coaxial joints, we could only find some that were very expensive, so we decided to develop our own.
We found that the head assembly from a VHS video recorder contained a rotating rf transformer, which transfers the signals from the 'flying' heads to the chassis. We replaced the coils in the transformer with single turn loops and, with a bit of care, produced a rotating joint with a 3dB insertion loss but more importantly less than 0.5 dB eccentricity.

Fig 3 Our rotary joint

The next job was to find some way of generating the circular timebase and locking it to our rotating antenna.

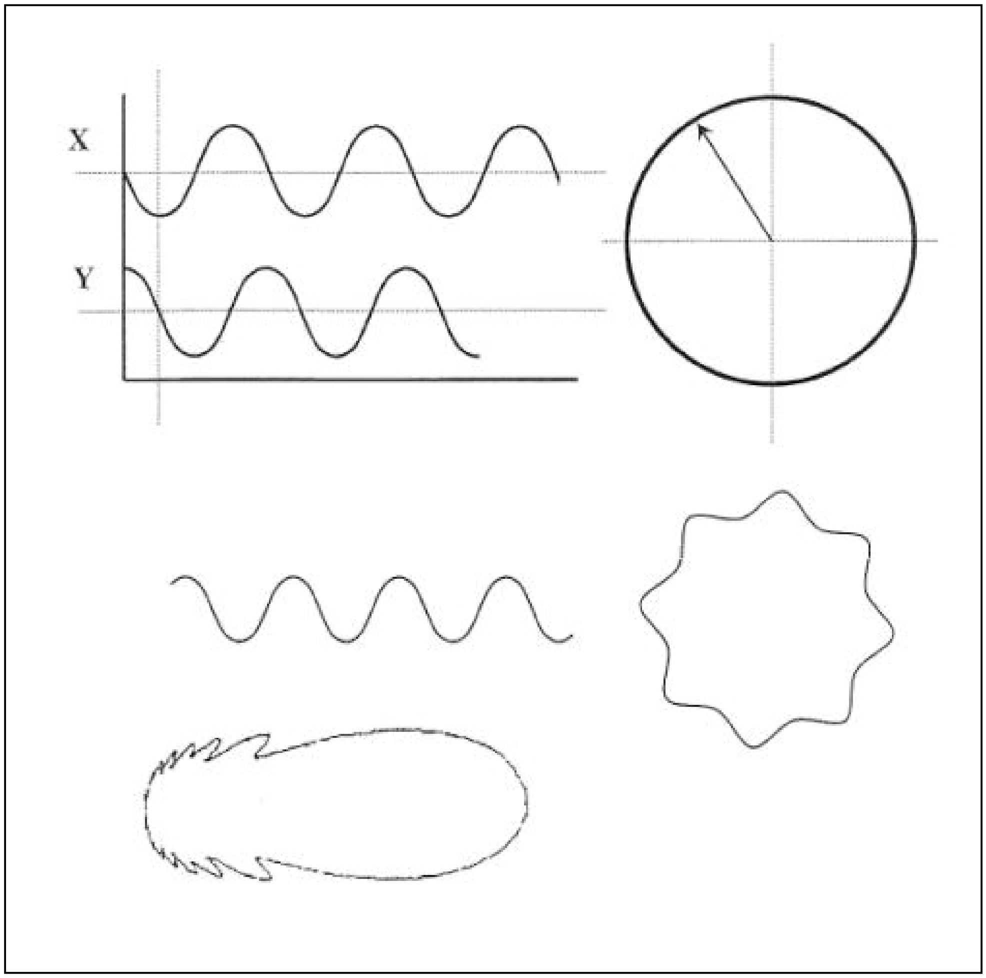
It was at this point that we discovered the 'Foxhunter's Bible' Transmitter Hunting by Joe Moell and Tom Curlee.
A chance remark in an email from an American amateur alerted us to this excellent publication which we immediately ordered from our local bookshop.
Unbelievably in one of the chapters there was a mention of a similar system to the one we were developing, using sine and cosine potentiometers to generate the timebase. In these days of digital electronics we decided to go for a more modern approach and use an all electronic solution.
In my recycling box I had some Hard Disk Drives which had optical shaft encoders to determine the position of the heads. I dismantled one and found that it had three optical rings, two with 208 steps and one with 4 steps.
Using typists correction fluid I converted the latter into a one pulse per revolution generator.
I now had all the signals I needed to control the timebase, 208 radial positions and one 'dead ahead' synchronisation pulse.
The next step was to generate the circular timebase signals.

Fig 4.

(a).

(b).

(c).



A bit of theory.

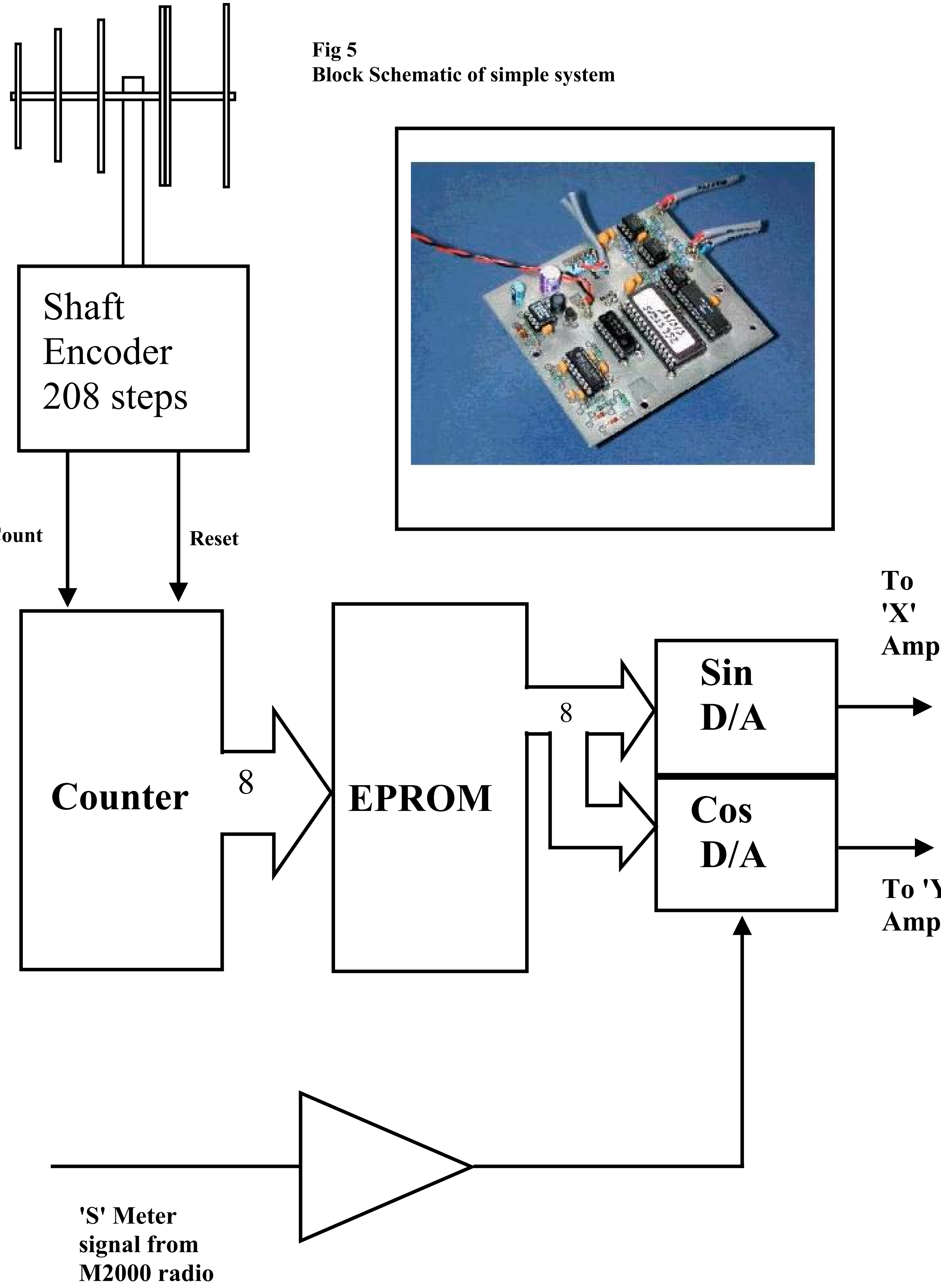
If you feed phase locked sine and cosine waveforms of equal amplitude into the X and Y plates of an oscilloscope, then you will generate a circular ***Lissajous display*** (a)

If you then modulate the amplitude of both these waveforms simultaneously, with another sine wave, you will modulate the diameter of this circle, and get a plot something like the one shown at (b).

Finally if you modulate the waveforms with the signal strength from the antenna, you will draw the polar plot of ***that*** signal (c).

So to provide a circular timebase I needed a captive sine and cosine waveform.
I sat down at the computer and did a bit of BASIC programming.
I generated a sine, and a cosine waveform, each containing 208 steps, which I blew into an EPROM ready for use in the display.

Fig 5
Block Schematic of simple system



As the antenna rotates, pulses from the shaft encoder clock an 8 bit counter which counts up through the memory locations of the EPROM.
The EPROM outputs a sine and cosine value for each location to the X and Y Digital to Analogue converters.
The converters generate a d.c. voltage for that corresponding position.
Simultaneously the buffered 'S' meter voltage is fed to the multiplying inputs of the D/A converters. This modulates the gain of the converters and hence, the amplitude of their outputs in direct proportion to the signal strength.
These two voltages then pass to the deflection amplifiers of the crt display, and in accordance with the theory described above, a plot of the signal strength is drawn on the c.r.t..

The 8 bit counter will of course count up to 255 if allowed to do so, but once every revolution a reset pulse from the second optical ring returns the count to zero at step 208.
This keeps the counter and hence the display timebase in synchronisation with the antenna rotation.

The Antenna.

We now had a system that could be used as an antenna test bed.
In open country with a low power transmitter someway off, we could easily plot the polar diagram of our antenna. Several evenings of experimentation followed until we settled on a five element J Beam antenna. (cut down from an 8 ele.)
The antenna gave a cardioid response, with no sidelobes to confuse the readings, and a front to back ratio of around 12dB.

Fig 6. Our open field test site.

The drawbacks.

The system worked well under test conditions and we successfully competed in our county championship for a whole season, winning by a narrow margin.
In practice the the VDU was too large to fit comfortably in the car. It had to sit on the floor between my feet (as navigator), and all the wires would get caught up in my legs every time I jumped out to investigate possible hiding places etc.
From a safety point of view this was a very unsatisfactory situation, operationally it was a nightmare!
The large folding maps that I was using on my knee obscured the display, and strong sunlight reflected off the screen. Finally there was the problem of mentally transferring the angle of detected transmission from the display up onto to the map.
Something had to be done to improve this situation, what we needed was a more compact, user friendly set-up.

'All comes to he who waits'

During the summer months we scoured the radio rallies for an alternative display. Then out of the blue John discovered a 2.5" diameter RADAR display module off a Phantom fighter aircraft on one of the flea fair stalls. At $50 he snapped the bargain up and then worried if the tube would turn out to be faulty. Of course there were no circuit diagrams and most of the electronics was 'tropicalised' in a thick clear coating of a varnish like material.

Fig.7. The display module

I set to and stripped the display to find that the EHT module ran off 24 volts and was a self contained unit that would supply most of the potentials for the crt. The only extra supplies that were required was the 9.7V for the tube heater and negative grid bias.
The heater was easy with a variable regulator, and I used the high voltage module recycled from an old fluorescent calculator display to give me up to -80 volts for the grid!

The rest of the electronics was junk, apart from the deflection driver and output transistors which were on the end plate of the module. I decided to build my own deflection amplifiers incorporating these transistors, as I reasoned they should be matched to the coils.
The amplifiers just used a couple of operational amplifiers and tied the output transistors into the feedback loop to keep the whole circuit linear.

I now had the problem of finding 24 volts for the EHT module. Our local military surplus depot came to the rescue. They had some ex-aircraft 400 Hz inverters that produced -32v from +32V. With a bit of modification I was able to get the inverter to produce -12 Volts from a +12 Volt input. An ideal situation, as now I had +/- 12V for my deflection amplifiers and 24V for the EHT supply. So the whole module could run off the car electrics!
I could now test the display and see if it was suitable for use in our system.
The new scan amplifiers and coils worked extremely well allowing me to move the trace around the screen at great speed without distortion.
But I soon found my next problem, the persistence of the phosphor.
Being white, the phosphor had a very short delay which left the readout looking like a tadpole swimming round rather than a coherent polar plot!
It looked as though we were going to have to add some kind of artificial persistence in the form of electronic storage.

The final design.

I set to and designed a dynamic storage system around Dual Port RAM. These devices have independent input and output ports both pointing at the same memory locations. This important feature allowed me to load the memory with signal strength data at the low 'antenna revolution' rate, whilst simultaneously reading the data out to the display at a much higher clock rate.
This created the impression of a continuous display due *now* to persistence of vision.

Whilst I was working on the re-design, I also had a stroke of luck with the antenna position shaft encoder. At work I had a broken graphics plotter come into the workshop as scrap. The unit contained some very nice optical shaft encoders made by Hewlett Packard which had 512 steps per revolution. This was an ideal opportunity to increase the resolution of the display from 208 steps to 512, (or as I decided in the end, as everything else was 8 bit), 256 points.

It also gave me the opportunity to add a mechanical adjuster to turn the encoder with respect to the rotator system. By placing a signal source directly in front of the vehicle, the adjuster is rotated until the displayed lobe is drawn 'dead ahead' on the crt. All misalignments in the system are removed in one go with this control, including any skew in the response of the antenna.

Figure 8 shows the new design using the dual port RAM and upgraded resolution.

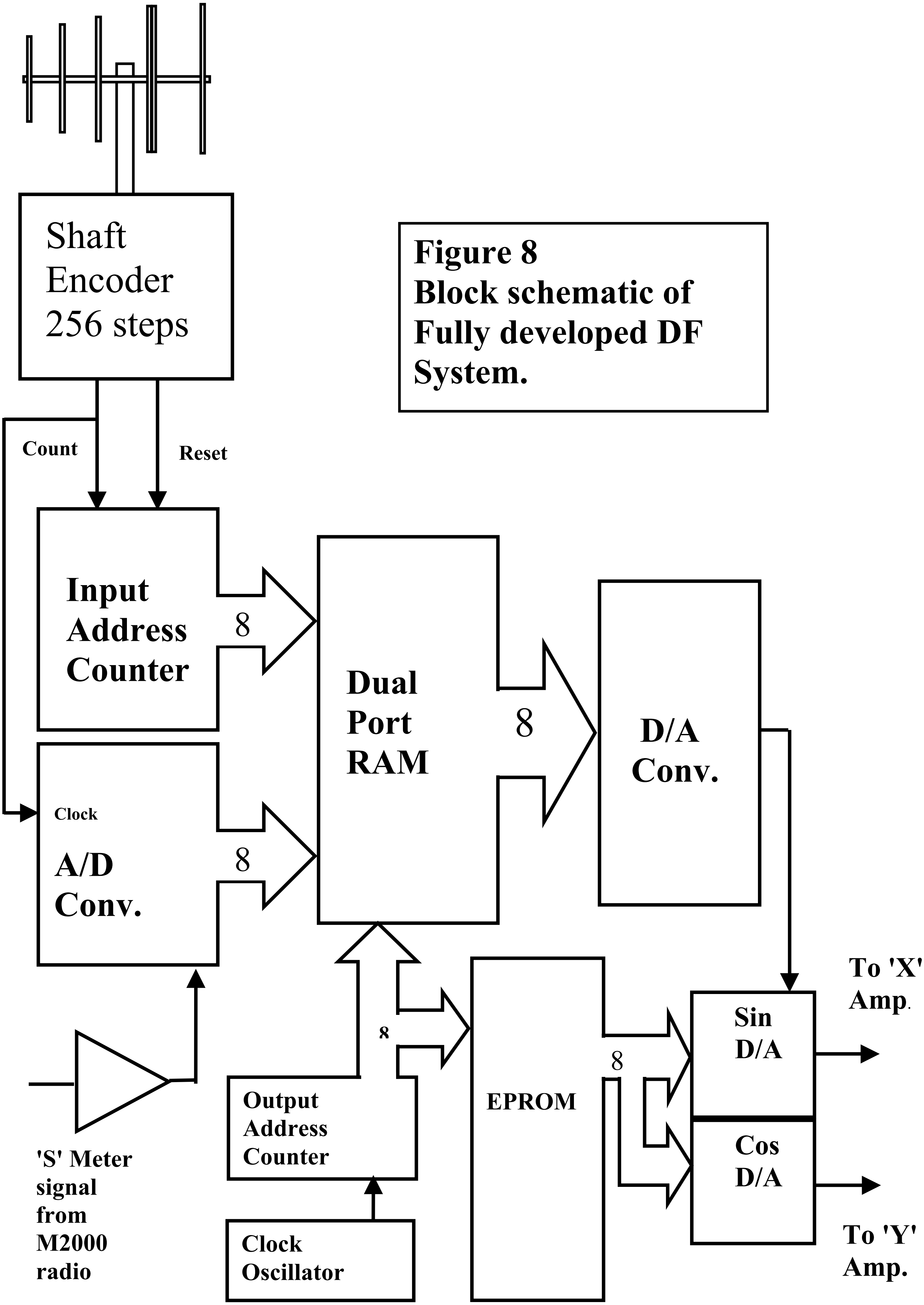
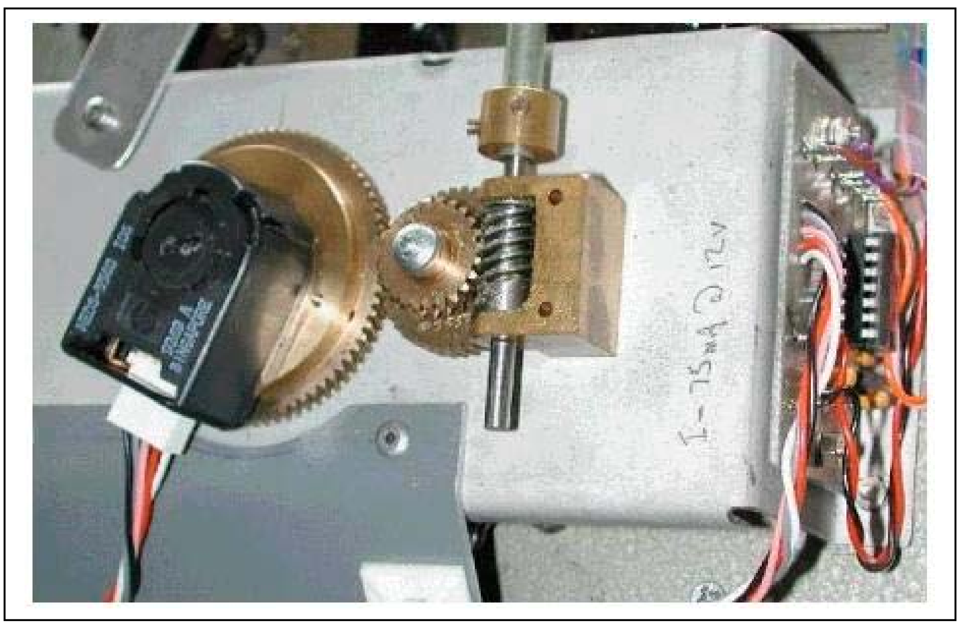


Figure 8
Block schematic of Fully developed DF System.

As before when the antenna turns, clock pulses from the shaft encoder drive an 8 bit counter that *now* progresses through the DP RAM input addresses. The same clock pulses are fed to the 'start convert' pin of an A/D converter that digitises the value of the 'S' meter voltage at that instant. An 8 bit number appears at the output of the converter that represents the magnitude of the signal at that position and is stored in one of 256 RAM allocations.

The antenna rotates continuously, storing data in the memory as it does so. At the 'dead ahead' position, a reset pulse from a second optical ring on the shaft encoder resets the address counter so that the antenna keeps in synchrony with the counter. (It was feared that under high speed travel conditions and the high resolution of the encoder, extra pulses could be generated due to wind pressure on the antenna and slight backlash in the mechanics.)

Fig 9. HP shaft encoder and mechanical adjustment to zero 'dead ahead position.
Divide by two circuit can be seen on extreme right.



On the output side of the system.
The clock oscillator provides pulses that advance the 'output address' counter. This counter steps through the output addresses of the Dual Port RAM and simultaneously, the EPROM address lines.
The EPROM as before is loaded with sine and cosine waveforms, now regenerated with 256 points. The stored 'S' meter levels in memory are output to the D/A converter which restores them to a varying DC level which, as before, is used to control the gain of the Sin and Cos D/A converters.
As the clock oscillator runs, the circular timebase is created and the signals are displayed on the c.r.t. The oscillator clocks the output system at a much higher rate than the input system is clocked by the antenna, and so the display is that of a continuous plot being updated at the rotational speed of the antenna.

Operational Report.

The system is built into a recycled instrument case and makes a very compact unit, that fits easily on the vehicle's parcel shelf.

Fig 9. The completed display unit

All the aforementioned problems with wires and maps were eliminated by this miniaturisation and the controls were much easier to access too.
We didn't have any problems with jitter on the display due to slack the mechanics, and the bus arbitration logic incorporated in the DP RAM invisibly takes care of any bus clashes.

The system has a wide dynamic range, with an indication of signal direction being displayed from:- a 'rock crushing' 6 feet away from the transmitter, to an extremely weak signal in the noise.
Since the completion of this system we have developed a noise detection add-on, that improves the sensitivity by a further 20dB's. The new circuit will give a full scale indication with as little as 0.5dB of quieting on the unsquelched FM background noise.

The three illuminated buttons on the front panel, control:-
a). Switching between standard signal detect and the new noise mode.
b). An 'inch' control to zero the antenna 'dead ahead' for high speed motoring between transmissions
c). Scan, (the rotation of the remote antenna)..

The large round control is of course the **RF attenuator**, 0-100dB in 10dB steps, this is connected in the lead from the antenna masthead preamp to the reciever and is adjusted to keep the display from overloading.

The **'S' meter** is driven from the buffered 'S' meter drive voltage out of the radio and has some rudimentary indications of 'miles down range' determined through extensive 'in the field' testing.

The **Gain** control varies the amount of 'S' meter signal fed to the electronics.

The **Bearing** control is another late addition which was borne out of item **5** in the system outline mentioned near the beginning of this article.
As can be seen on the display there is a sharp 'glitch' on the peak of the polar plot on the c.r.t.
This is a 'pip' marker that can be rotated 360 degrees round the display. It is moved by the navigator to select his best guess at the incoming direction on the display. Data generated internally by the use of this control, is relayed via a ribbon cable to a clear mapping handset that transfers this bearing to the map via a series of leds.

C.R.T. display and corresponding led illuminated on plexiglass handset.

The system has performed extremely well and we have been able to stay at the top of the foxhunt championship now for the last 4 seasons.
Dispensing with paper maps, we have adopted a GPS based navigation system using a laptop computer and GPSS software. (See :- http://www.gpss.co.uk)

This final picture shows the unit installed in John's vehicle and nicely demonstrates my comments about the improved operating position.
In part two I shall be discussing in more technical detail how the system works.