Dear Paul,

Thanks for your hospitality. I think it was a useful day. Looking forward to next time, i.e. Thursday 1/8. Best wishes to you and all concerned.

Ralph

**Waveform design for MIMO radar**, **Lulu Wang**  
 For monostatic radar, Lulu was studying the literature regarding various alternative criteria for the resolution capability of waveforms, and regarding absolute limits to that capability. However, in a MIMO radar with a significant diversity of MIMO paths, there will be a significant number of parallel transmissions (ideally the same as the number of receivers), and then the primary limit on detection performance will probably be neither thermal noise nor clutter, but mutual interference between the transmitters.   
 If the targets are near-enough stationary, suitable mutually orthogonal modulations will then be monochromatic rectangular bursts of duration T, whose frequencies differ by integral multiples of 1/T, or otherwise suitable PRN code sequences. However, for significantly mobile targets, Doppler effects are liable to spoil their orthogonality, and then suitably orthogonal chirp modulations should be more appropriate, since their nature is virtually unchanged by Doppler effects. To cover intermediate scenarios, it may however be interesting to explore the scope for imposing a limited number of well-spaced pseudo-random phase steps onto a chirp waveform.

As a more general point, it is well known that the most sensitive technique for detecting **the presence** of a signal is to correlate it with a template of its ideal waveform. However, this is not the best process if we are looking for some other parameter than the presence of the signal, e.g. its timing. Timing information is proportional to the gradient of the waveform and therefore – given an adequate S/N - it is optimised by correlating **the differential** of the observed waveform with **the differential** of its ideal template. This differential is best derived by subtracting the waveforms at a spacing which is a suitably small fraction of the auto-correlation time of the differentials.

**Direction-finding RFID tag readers, Jun Qian, Paul Brennan**  
 A two-element antenna can form a null in any desired direction. Hence n separate outputs from the two antennas can form n separate beams, each with its own null. The proposal is to form, say 7 such beams, with equally-spaced nulls. The pattern of relative amplitudes of an echo of these 7 antenna patterns is then characteristic of the target’s azimuth.   
 For angular precision independent of the actual direction, the spacing between these patterns should probably match the width of the nulls.   
 The scheme could work with the voltage or power or dB pattern. However, the dB pattern is probably best, since it yields the deepest, i.e. sharpest nulls.

The present implementation derives the patterns of 7 relative amplitudes at 1° interval and, for each tag, finds the best fit. However, it might be sufficient to

• match to, say, 7 reference patterns where a target is in a null and to the 7 midway ones,

• find the two best matches,

• interpolate between them on the basis if their relative strengths.

It may be possible - and perhaps useful – to devise an analogue, for this application, to the differential processing algorithm proposed above for radar resolution. However, 7 nulls, spaced by 20° degrees, would then have to be replaced by 7 **differential pairs of nulls**, where the two members of the pair are spaced by, say 5°.

An experimental implementation of the scheme, whilst confirming its validity and effectiveness, showed that both the measured reference patterns and the measured target signals are seriously impaired by multi-path contamination. This effect is easily recognised – and hence correctable – by human eye. It should be possible to devise a computer algorithm to achieve the same benefit. This might take the form of

• finding the best fit to an “ideal” reference waveform

• adapting a number of appropriate simple shaping parameters to distort the reference waveform,  
 so as to optimise this fit.

A more fundamental approach is to reduce the multi-path contamination itself. A narrower beamwidth would not only scale down the number of unwanted path *pro rata,* but would also drastically reduce the extra path-lengths, and so, hopefully, reduce the deleterious effect of the remaining unwanted signals. For this purpose, the two dipole antennas might be replaced by an array of four. We might then apply to these (in our example) 7 different phase slopes, thus forming 7 distinct narrower beams. Each of these would then be treated as two pairs, comprising respectively antennas 1-3 and 2-4, for forming the appropriate null.

**Reducing within-ship electromagnetic interference in naval vessels, Ajmal Gharib.**

Ajmal created some FDTD computer models of the topside structure of ships and validated these by comparison to physical models, created by wood or foam plastic, coated with conducting paint. Mostly the physical and computer models corresponded quite satisfactorily, but there was a major discrepancy at one frequency. I noted

• that this had all the characteristics of a resonant effect,

• that the height of the mast above the superstructure was consistent with resonance.

• that the practical conductivity of the paint – and hence the Q of the resonance,  
 might well fall well short of that assumed in the FTDT model.

I therefore suggested applying more or better metallic paint, to test this hypothesis.

More generally, the computation was significantly less accurate where there was no direct line-of sight between the two antennas involved. However, this configuration also implies that any interference will be much weaker, and so any error in estimating the strength of that interference is much less significant

We also discussed many aspects of the conditions in which mutual interference can cause practical trouble, and what approximations may be permissible when dealing with very high frequencies, where both forms of modelling lose some of their validity. However, these discussions are probably not worth recording here.

**Electro-Magnetic Hyperhermia for medical applications, Alann Al-Armaghany.**

The specific application now investigated is to test for hardening of the arteries by testing whether electro-magnetic hyperthermia will dilate the arteries, so increasing local blood-flow and hence oxygen levels, as monitored by IR sensors.

Alann has made impressive progress in the design and construction of appropriate equipment. He found that a patch with circular-polarisation yields a much more uniform thermal footprint than a linearly polarised one. However, for the best uniformity, the circular polarisation needs the symmetry of 4 feed points, rather than just 2. Alann sweeps the frequency, to find that best matched to the skin of the given patient.

Skin heating continues to be a major problem, because of discomfort or possibly actual harm to the patient, and because its effect is likely to mask the one we are seeking to observe.

I had suggested using a superstrate which:

• is low-loss,

• has a high dielectric constant matching that of the skin, to avoid mismatch at this interface,

• due to the resulting shortening of the in-medium wavelength, can accommodate a circularly-

symmetric pattern of multiple antennas, which combine to focus coherently on their axis of

symmetry,

• which is a good thermal conductor, for skin cooling.

A material of low dielectric constant, which, during its formation, is amenable to loading with aluminium or copper powder, to yield the desired high dielectric constant and high thermal conductivity, would fit the bill. Alann is still looking out for this.

To ensure the device does not generate any undesirable or unauthorised external radiation, we might provide an external metallic screen, coated on its inner surface with radar-absorbent paint.

Best wishes to all concerned,

Ralph