Correlation techniques applied to antenna pattern measurement

P.S.H. Leather, J.D. Parsons, J. Romeu, S. Blanch and A. Aguasca

A correlation processor based on the excellent periodic autocorrelation properties of maximal-length pseudorandom binary sequences has been used in antenna pattern measurements to resolve the direct (wanted) path from any unwanted multipath components. A simple implementation of the technique has been used to make measurements in a controlled environment; the results show that the multipath effects are almost completely eliminated and an accurate pattern measurement is obtained.

Introduction: Antenna pattern measurements are often distorted by extraneous signals that reach the test zone as a result of scattering from obstacles in the vicinity of the antenna range. These 'multipath' signals have to be eliminated or their effects reduced, if accurate pattern measurements are to be obtained. A number of techniques that analytically or experimentally compensate for multipath effects are described in the literature [1, 2] but these are often complicated and/or expensive to implement. Relatively simple practical techniques based on signal processing are available, however [3–5], and have many attractions. In this Letter we describe results obtained using a correlation technique.

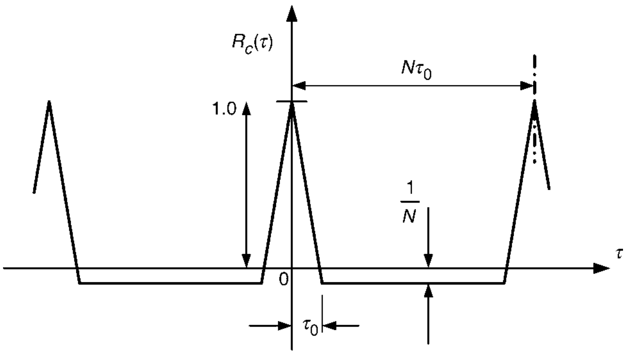

Fig. 1 *Normalised autocorrelation function of maximal-length PRBS*
τ_0 is chip period, N is sequence length

Correlation technique: The swept time delay cross-correlation (STDCC) technique is well-known. It provides the basis for many so-called channel sounders that have been used for several years to characterise dispersive radio channels [6, 7]. However, the technique can also be used to resolve the direct (wanted) path in antenna ranges from any unwanted multipath components [4, 5]. The principle underlying the technique is that maximal-length pseudo-random binary sequences (PRBS), alternatively known as M-sequences, possess excellent periodic autocorrelation properties [8], as illustrated in Fig. 1, which shows a normalised autocorrelation function. The residual, negative, excursion is inversely proportional to N, the length of the sequence and the base width is proportional to the clock period (τ_0). Long sequences with high clock rates therefore provide greater dynamic range and better time-discrimination properties. In a typical STDCC channel sounder transmitter, a CW carrier having a frequency at the centre of the measurement band is 'spread' using phase-reversal modulation and a PRBS as the modulation waveform. An amplified version of this signal (RF bandwidth $\sim 2/\tau_0$) is transmitted. In the receiver the incoming signal is correlated with a locally-generated sequence, which is identical to the one used at the transmitter, but clocked at a slightly slower rate. The effect of this is that the two sequences appear to slide past each other slowly. Whenever there is alignment between any incoming sequence and the locally generated sequence, there is a peak in the detected receiver output; at other times the detector output is low-level noise. The result is a plot of the received multipath components against time delay, the latter being time-scaled by a factor equal to the transmitter clock frequency divided by the difference between the transmitter and receiver clock frequencies. Individual multipath components are thereby identified and measured. The time-delay resolution capability of the system is approximately equal to τ_0 and the maximum unambiguous measurable time-delay is $N\tau_0$.

Antenna pattern measurements: Equipment comprising a transmitter and receiver as described above can be used directly in an antenna range to distinguish the direct (line of sight) component from any multipath components [4]. Although reciprocity applies, it would be normal to use the transmitter to feed the range antenna (RA) and to attach the receiver to the antenna under test (AUT). As an example, a transmitter clock rate of 50 MHz and a sequence length of 1023 bits ($2^{10} - 1$) would permit a time-delay resolution capability of 20 ns (6 m spatial resolution) and a maximum measurable time delay of 20.5 μs. All components of the received signal are measured but only the LOS component at each rotational position of the AUT is used to plot the antenna polar pattern.

An interesting variation of the configuration is also possible [5] and this was the system used in the experiments reported here. Instead of generating a separate PRBS at the receiver, the transmitter PRBS is fed forward to the receiver via a time delay, which is exactly the same as the delay along the LOS path (including delay in the electronic hardware). The chip rate is therefore the same at both ends of the path. At the receiver, the direct component is completely correlated but all multipath components having a delay greater than τ_0 have very low correlation and are effectively eliminated. This system architecture is simpler than that used for channel sounding and provides the antenna polar pattern directly. The spreading and de-spreading functions may be implemented at the final radio frequency or at an intermediate frequency.

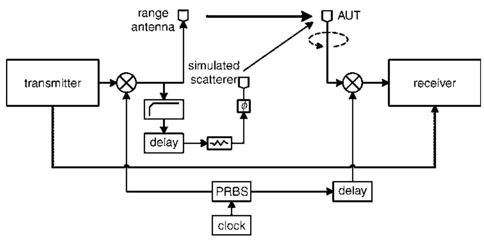

Fig. 2 *Schematic representation of measurement configuration*
In practice, a network analyser realised transmitter and receiver functions. Antennas and positioning equipment housed in anechoic chamber measuring approximately $9 \times 7 \times 7$ m ($L \times W \times H$)

Experimental results: To validate the approach described above, the configuration shown in Fig. 2 was used to conduct experiments in a controlled environment in which the presence of a multipath component is simulated by radiating a signal with adjustable amplitude and a delay set by an arbitrarily long cable, from an additional antenna. The physical position of the additional antenna determines the direction from which the multipath component is received. The level and delay of the signal radiated from this antenna can be independently adjusted, while performing measurements in a controlled environment such as an anechoic chamber. In this way the full extent of the technique can be assessed.

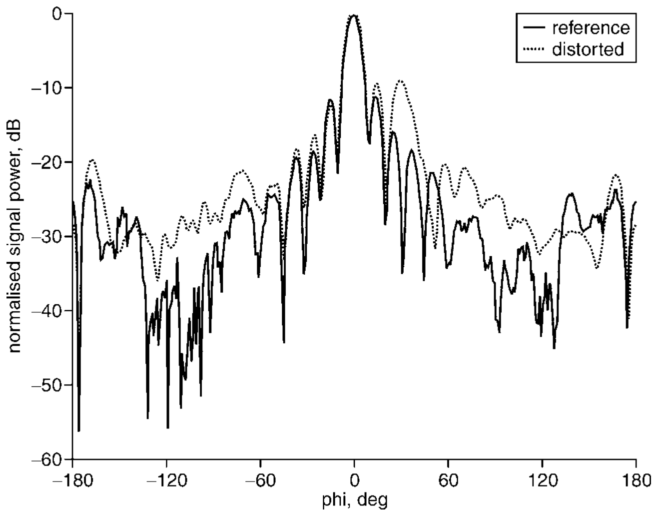

Fig. 3 *Azimuth plane cut of measured radiation pattern*
——— reference measurement in absence of simulated multipath
· · · · · · measurement in presence of one simulated multipath component at 10 dB below wanted signal

In the experiment reported here, a PRBS of length 4095 bits with a chip rate of 4.5 MHz ($\tau_0 = 222$ ns) was used as the modulating waveform. The multipath signal was delayed so the time difference between the direct and multipath signals was 315 ns; the interfering signal is therefore well decorrelated. The measurement was based on the HP8530 network analyser. This instrument is designed for both CW and frequency swept measurements; it acted as transmitter and receiver.

Using this experimental configuration, the radiation pattern of an eight-element slotted waveguide array was measured under three different conditions. First, a reference measurement was made in the (physical) presence of the additional antenna, but with no radiation from this antenna. A second pattern measurement was then made with the antenna radiating a delayed signal at a level about 10 dB below the wanted signal. The antenna was located at 40° from the direction of the direct path. The results of these two measurements are shown in Fig. 3. It is clear that the multipath produces a very noticeable distortion in the measured pattern.

Fig. 4 shows the measured pattern with the multipath signal present and the correlation technique in use. The original reference measurement is shown for comparison. It can be seen that that the original measured pattern has been recovered, and the effect of the multipath component has been almost completely cancelled.

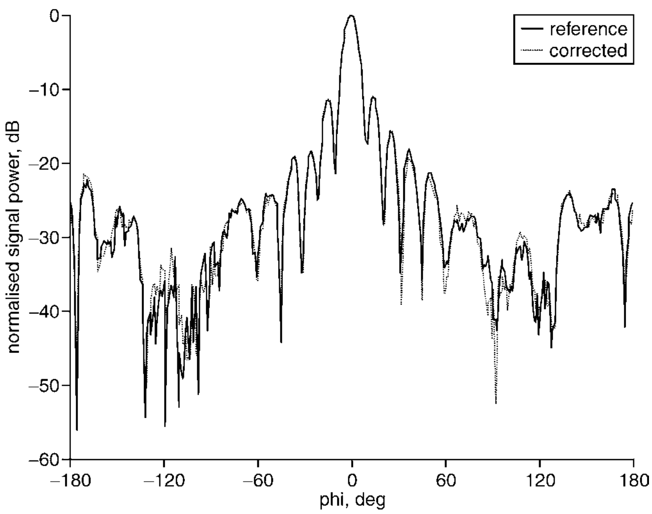

Fig. 4 *Azimuth plane cut of measured radiation pattern*

——— reference measurement in absence of simulated multipath
– – – – corrected measurement in presence of one simulated multipath component as above, but with correlation technique in operation

Conclusions: The feasibility of using a correlation technique to cancel multipath effects in antenna measurement ranges has been demonstrated. The experimental configuration devised for this work allows an assessment of the technique in a controlled manner in an existing antenna measurement facility, but the technique itself is applicable in both indoor and outdoor ranges. The correlation technique is attractive commercially because of its effectiveness and simplicity. The implementation described here, with the PRBS fed forward via a suitable delay, is much simpler and gives more direct results than the alternative swept-correlator system. In practice the geometry of the environment and the physical size of the AUT influence the choice of chip rate. The bandwidth of the antennas used has to be sufficient to accommodate the transmitted RF spectrum.

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P.S.H. Leather and J.D. Parsons (*Fizzle Technologies Ltd., 70A, Freshfield Road, Formby, Merseyside L37 7BQ, United Kingdom*)

E-mail: press@fizzletechnologies.com

J. Romeu, S. Blanch and A. Aguasca (*Universitat Politècnica de Catalunya, Barcelona, Spain*)

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