AT/20.1.1/034

BANDWIDTH SYNTHESIS AND MOSAICING - CONSTRAINTS ON INTEGRATION TIMES

R.N.Manchester and M.J.Kesteven

The advantages of bandwidth synthesis, particularly for the 6km Compact Array, were discussed in AT/20.1.1/014. In that document it was assumed that the switching cycle had to be completed in the visibility integration time of 5 or 10 seconds defined by the allowable reduction in the amplitude of sources at large radial distances from the phase centre (cf. AT/20.1/006,008). This imposes some severe requirements on the control electronics. Discussions of ultra wide field mapping using multiple antenna pointings within an integration cycle (mosaicing) (cf. AT/16.2/012) have similar implications.

It was pointed out by R.D.Ekers (AT/20.1.1/033) that the amplitude reduction criterion is not the appropriate one for consideration of switching times. For mapping to the first null of the primary beam pattern, it is required that the uv-plane be fully sampled; i.e., sampled every half antenna diameter in this plane.

In the radial direction, the basic spacing increment is set in concrete at 15m. Complete filling with this increment is possible for the 3 km array but not the 6 km array (AT/10.1/036). The minimum spacing of tracks on the uv plane is 15m in the u direction and 15m.sin(dec) in the v direction. Even for complete filling the uv-plane will not be fully sampled for dec north of -47 deg (AT/20.1/006) and there will always be substantial gaps for the 6 km array.

In the circumferential direction, the sampling interval is proportional to integration time and distance from the uv origin, i.e. the baseline. For full sampling, the integration time is limited to

$$dt = 0.011/(\omega * B) \text{ seconds}$$

where B is the maximum baseline length in km and omega is the rotation rate of the earth. For the 6km CA this gives dt = 25 seconds. If the allowable sampling interval is increased to from 11m to 15m to correspond to the radial sampling, then dt = 35 sec. Since the sampling interval is proportional to baseline, over most of the uv-plane the sampling interval will be satisfied even with dt = 35 or 40 sec.

The radial gaps can in principle be filled by observing at different frequencies. In most cases, the correlator bandwidth will not be sufficient and switching of the centre frequency will be required, i.e., bandwidth synthesis. If the minimum time for frequency switching is 5 seconds (cf. AT/20.1.1/032), then we are restricted to five different frequencies by the 25 second limit given above. In practice, because of the reasons given above, this could probably be relaxed to a limit of eight frequencies.

For mosaicing, for four different antenna pointings, the time per pointing would in the same way be limited to 10 seconds at most.

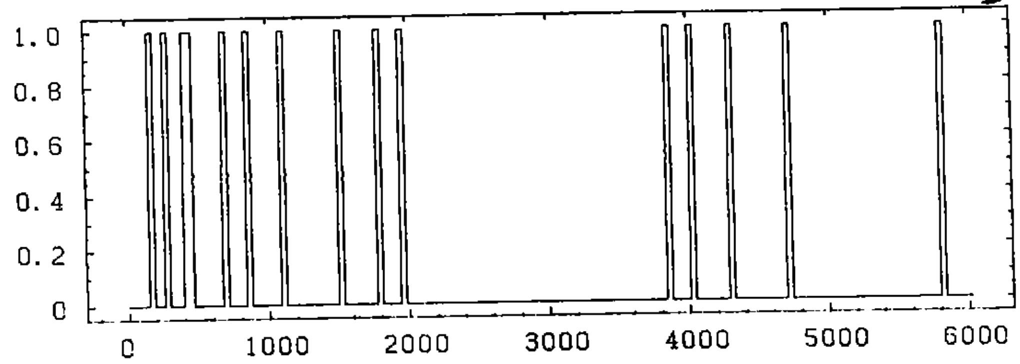
It should be mentioned that bandwidth synthesis is limited in its application. Obviously it cannot be used for spectral-line observations. With present analysis procedures the frequency coverage is restricted for sources in which there is a significant range of spectral indices, for example, radio galaxies. Some work has been done on simultaneous solution for images of total intensity and spectral index but this is not yet routine. Polarization observations will be restricted in frequency coverage by Faraday rotation. In principle, this could also be solved for, but as far as we are aware this has not yet been attempted.

To illustrate the effect of bandwidth synthesis on the uv-coverage for the 6km array, we have taken a 12-day minimum redundancy solution (cf. AT/10.1/036) where the 6km antenna remains on the end station. (A principal rationale for use of bandwidth synthesis is to avoid moving the 6km antenna.) For each day of this sequence we have computed the radial uv coverage for (a) no bandwidth switching, and three bandwidth switching patterns,

(b) eight frequencies over a total fractional frequency range of 8%, which is the fractional bandwidth of the 128 MHz correlator bandwidth at 1.6 GHz and of the order of the largest fractional gaps in the uv coverage after 12 days, (c) four frequencies over a total fractional frequency range of 33%, the largest obtainable in one band (20cm) for the AT, and (d) eight frequencies over the 33% band. The baselines for each day were convolved with a triangular function of base 40m representing the effective weighted sampling of the uv-plane in the radial direction and accumulated for successive days. The uv coverage for these four cases is illustrated in Figures 1a-1d. In each figure the radial support of the convolved and accumulated function is given for one, four and twelve days and the full function (the spatial spectral sensitivity function) is shown for the twelve day case. The completeness fraction or fraction of the 6km baseline covered by the support is given for the four cases as a function of number of observing days in Figure 2.

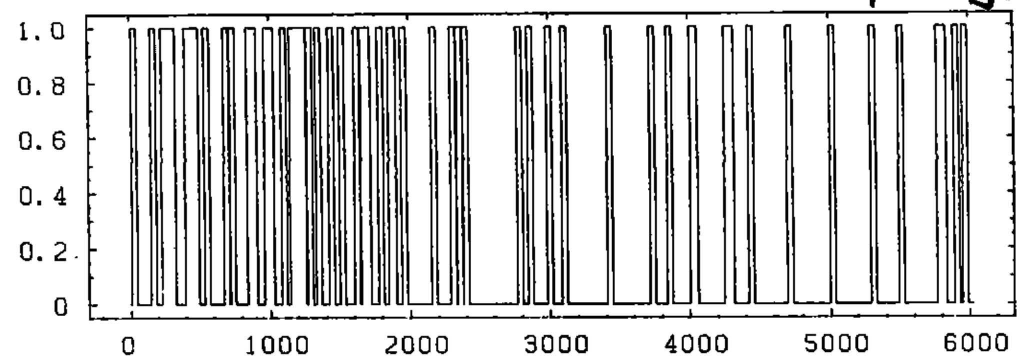
Clearly there are considerable benefits to be obtained from bandwidth synthesis. Not only is much better coverage of the uv-plane obtained, it is obtained more quickly. There is very little to be gained by observing a given field for more than four days with bandwidth synthesis. The benefits appear to be approximately linearly proportional to number of frequencies. There is little or no benefit in using a frequency coverage larger than 8% as far as uv-coverage is concerned. If one is not simultaneously solving for spectral index, then there is a positive advantage in using the smaller frequency coverage; if one is making the simultaneous solution, then better results will be obtained with wider frequency coverage including switching between bands.

1 day



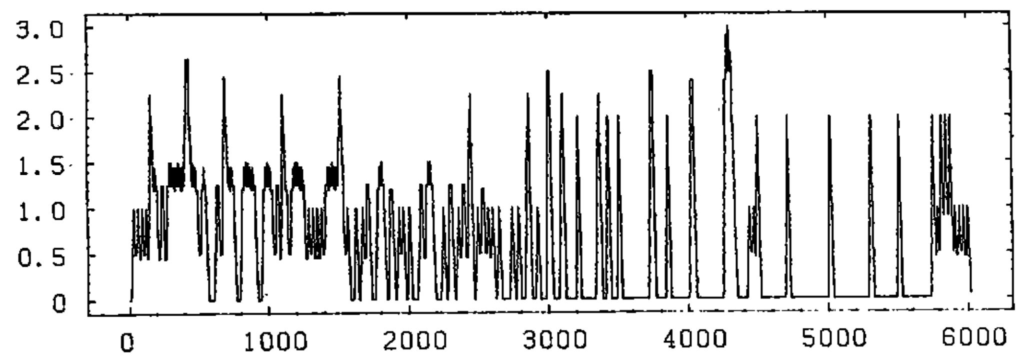
Completeness fraction : 0.096

4 days



Completeness fraction : 0.329

12 days



convolving function

1.000	0.950	0.900	0.850	0.800	0.750	0.700	0.650
0.600	0.550	0.500	0.450	0.400	0.350	0.300	0.250
0.200	0.150	0.100	0.050	0.400	0.350	0.300	0.250

frequencies
1.000

Completeness fraction : 0.604

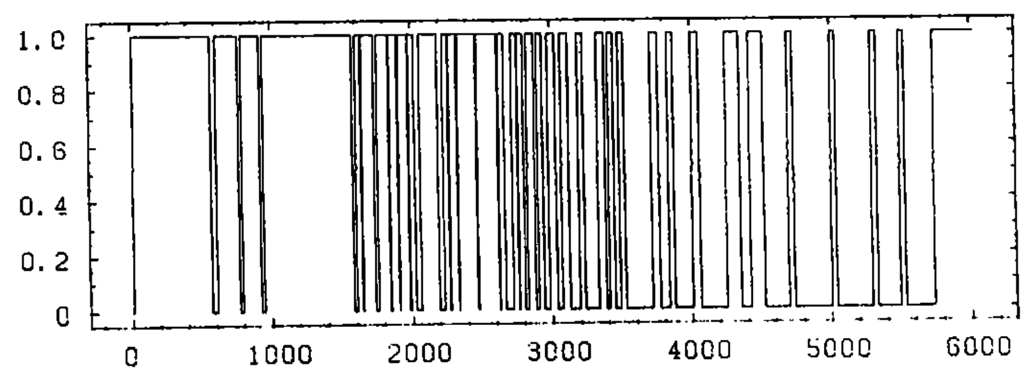
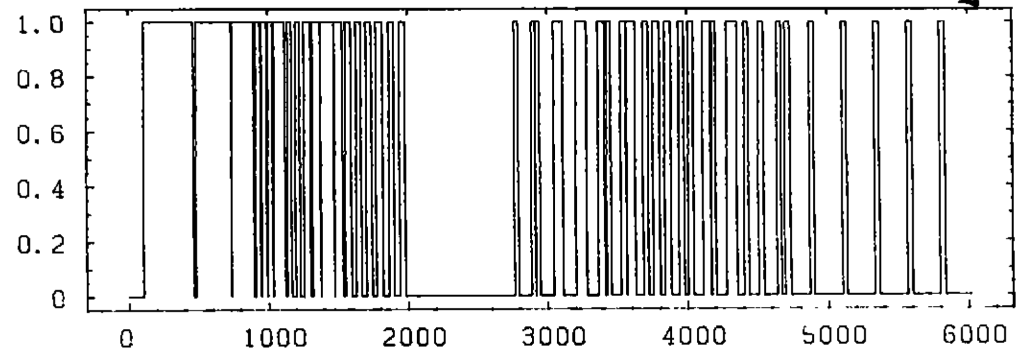


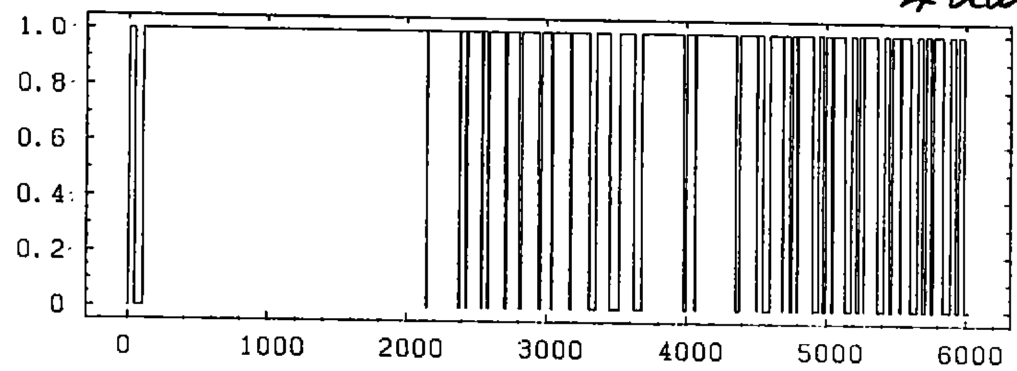
Fig. 1(a). No BW switching.

1 day



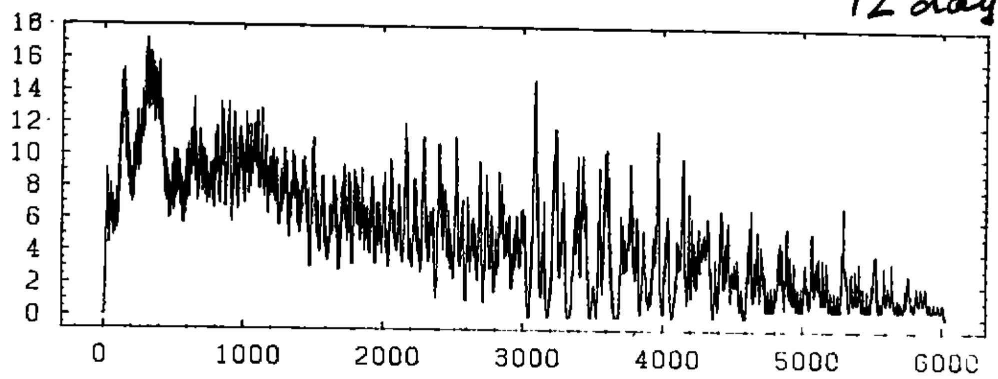
Completeness fraction : 0.495

4 days



Completeness fraction : 0.854

12 days



convolving function

1.000	0.950	0.900	0.850	0.800	0.750	0.700	0.650
0.600	0.550	0.500	0.450	0.400	0.350	0.300	0.250
0.200	0.150	0.100	0.050	0.400	0.350	0.300	0.250

frequencies

1.000	0.980	0.920	0.880	0.840	0.800	0.760	0.720

Completeness fraction : 0.984

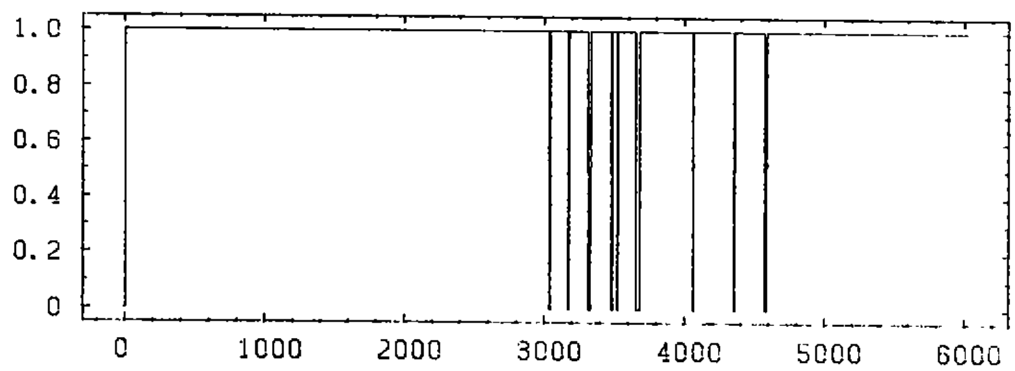
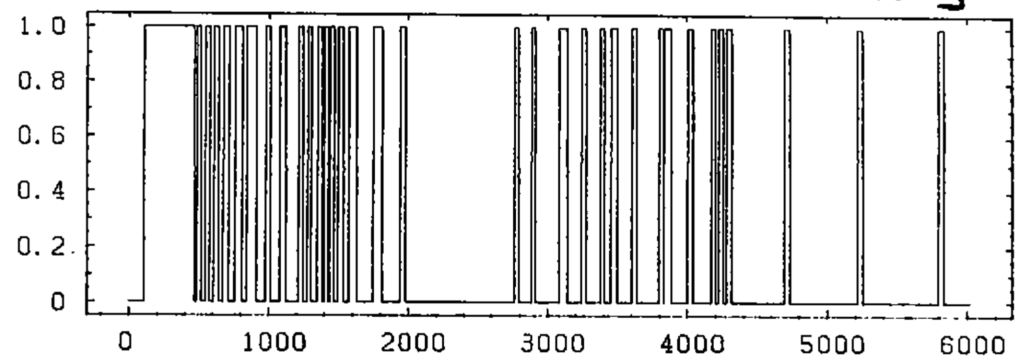


Fig. 1(b) 8 frequencies, 8% BW

1 day

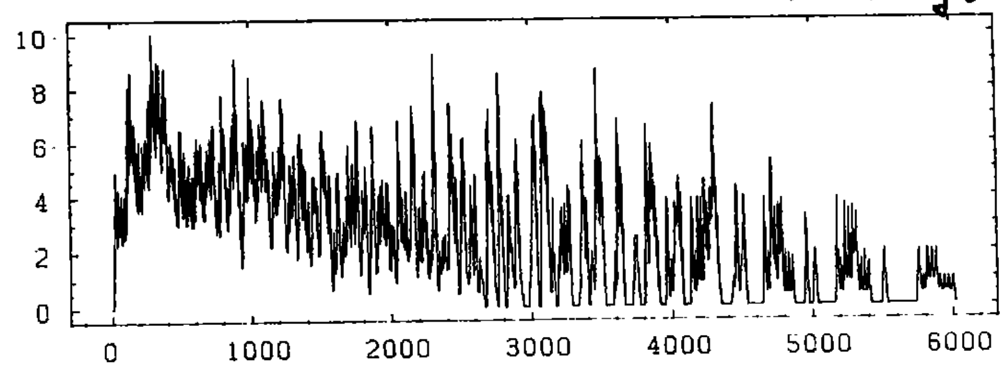


Completeness fraction : 0.273

4 days

Completeness fraction : 0.654

12 days



convolving function

1.000	0.950	0.900	0.850	0.800	0.750	0.700	0.650
0.600	0.550	0.500	0.450	0.400	0.350	0.300	0.250
0.200	0.150	0.100	0.050	0.400	0.350	0.300	0.250

frequencies

1.000	0.900	0.810	0.720

Completeness fraction : 0.831

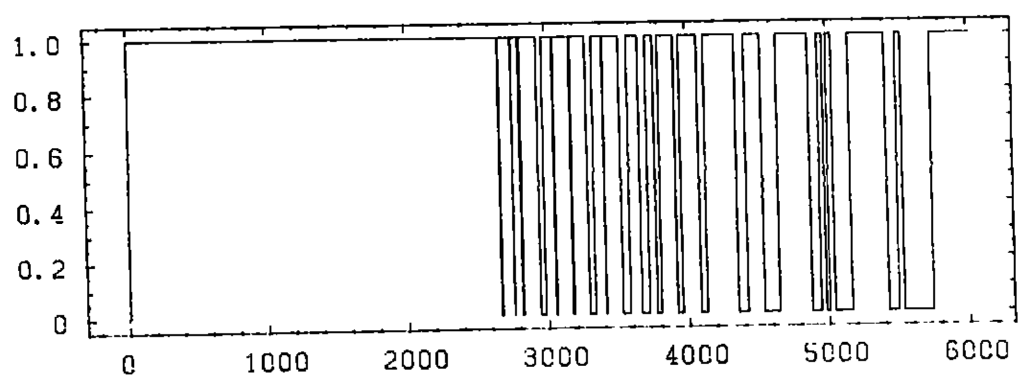
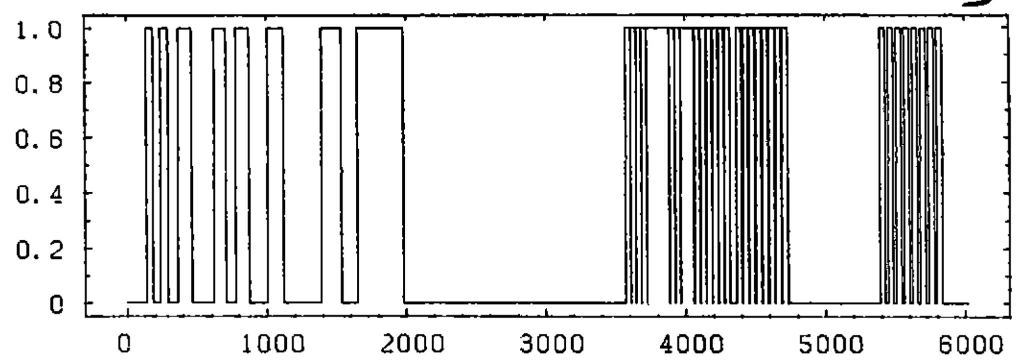


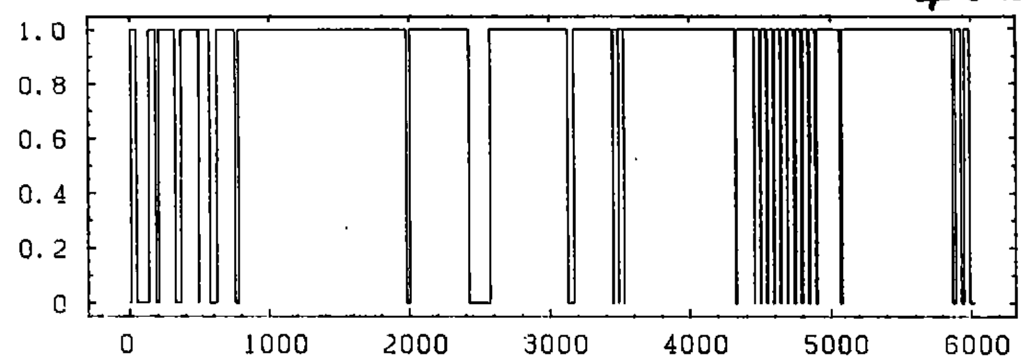
Fig. 1(c) 4 frequencies, 33% BW

1 day



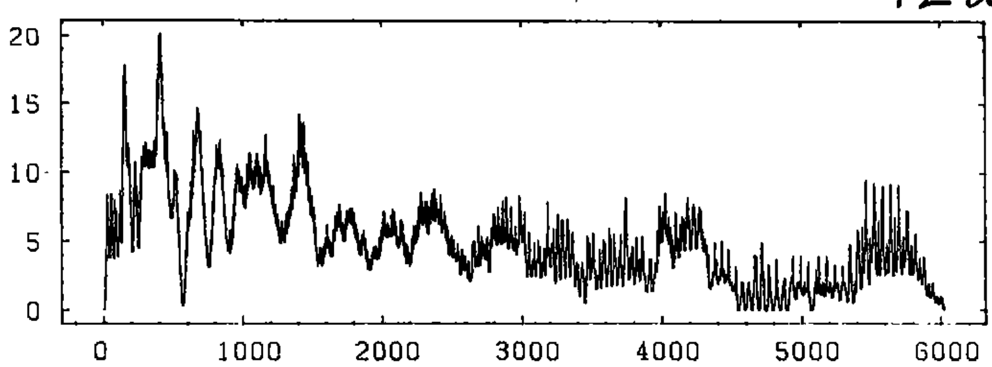
Completeness fraction : 0.981

4 days



Completeness fraction : 0.892

12 days



convolving function

1.000	0.950	0.900	0.850	0.800	0.750	0.700	0.650
0.600	0.550	0.500	0.450	0.400	0.350	0.300	0.250
0.200	0.150	0.100	0.050	0.400	0.350	0.300	0.250

frequencies

1.000	0.990	0.980	0.970	0.960	0.950	0.940	0.930

Completeness fraction : 0.982

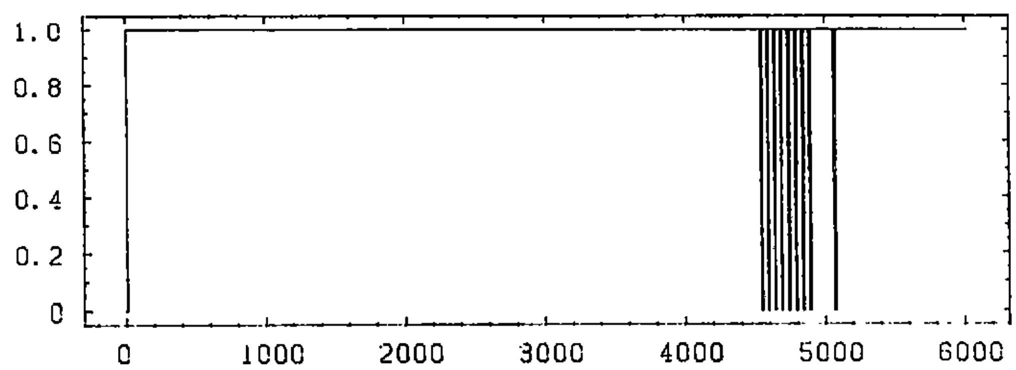
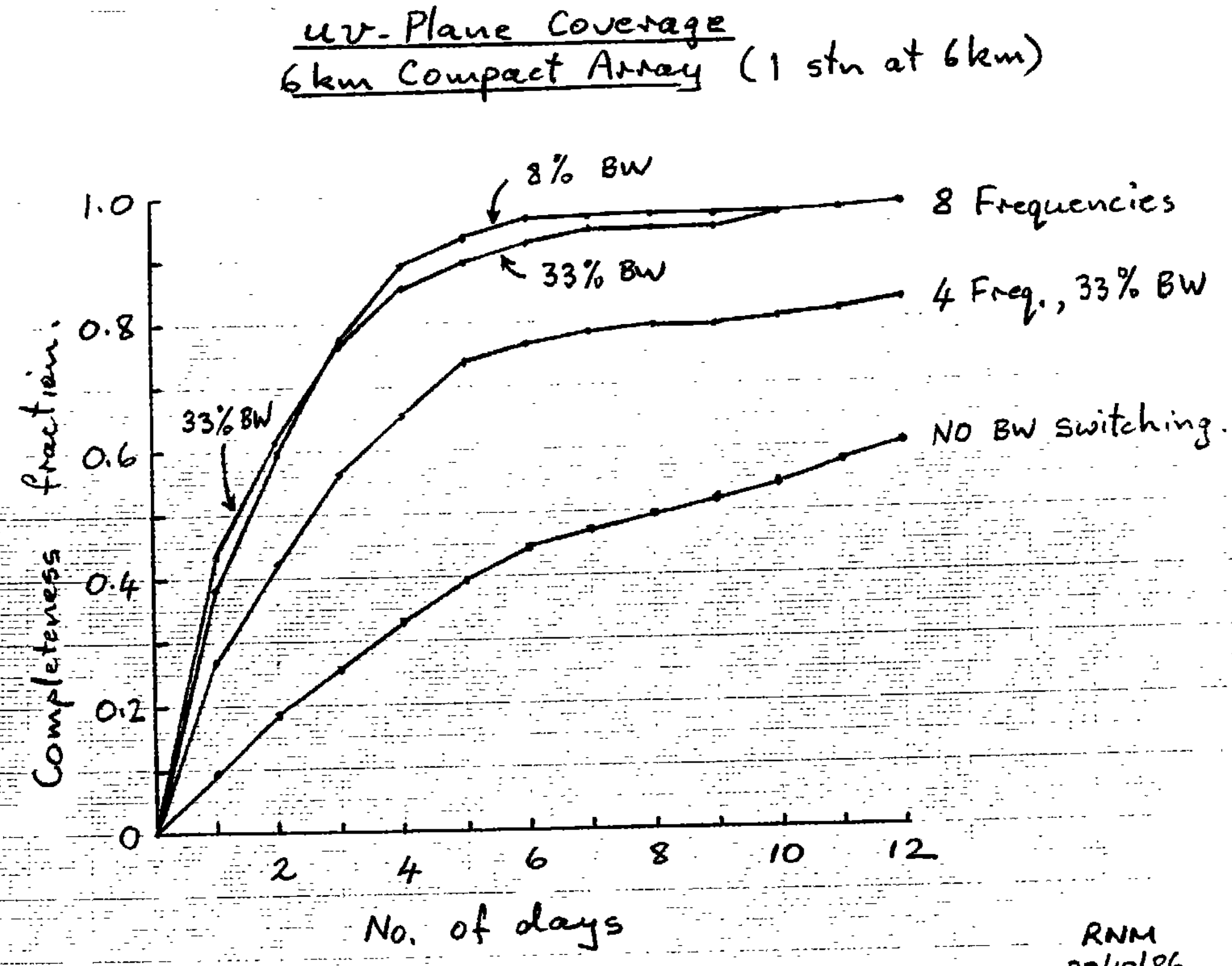


Fig. 1(d) 8 frequencies, 33% BW



RNM
27/10/86
(DMR61)

Fig. 2.