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Another Look at the Great Area-Coverage Controversy of the 1950's

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In the immediate aftermath of WW2 there sprang up an international argument over the relative merits for aerial navigation of area-coverage radio navaids versus point-source systems. The United States was in favour of point-source whereas the UK proposed area-coverage, systems for which had successfully been demonstrated under very adverse conditions during the war. It rumbled on for many years, not being finally settled until the ICAO Montreal Conference of 1959 decided for point-source. Since then, VOR/DME/ADF/ILS have been the standard aviation radio navaids and there seems little likelihood of any change in the near future, GNSS notwithstanding, if one discounts the phasing-out of ADF. It now seems sufficiently in the past to perhaps allow a dispassionate evaluation of the technical arguments used at the time–the political ones can be left to another place and time.

KEY WORDS

1. Radio navaids. 2. GEE. 3. DECCA. 4. VOR/DME.

1. HISTORICAL BACKGROUND. The original use of radio for aerial navigation was direction-finding. Hertz himself demonstrated the directional properties of a simple loop antenna and more elaborate antennas improved this to the point where accuracies of a few degrees were obtainable. Direction-finding from an aircraft to a ground beacon was problematical both because of the technical problem of re-radiation from the aircraft's own structure and the navigational one of, if there was appreciable drift, virtually ''chasing one's own tail''. This led to emphasis being placed on methods of direction-finding from the ground to a transmitter carried on board an aircraft, once aircraft had become big and powerful enough to carry a radio transmitter and a wireless operator. On the ground, space was available to erect large antenna systems and calibrate them properly. A fix could be obtained on an aircraft by the use of (preferably) three direction-finding stations and its position, calculated by ground operators, transmitted back to the aircraft. This saved the pilot the trouble of working it out for himself and the method became quite popular. It was the system used by the German Zeppelins in WW1 and by almost all civil air traffic in Europe right up to the outbreak of WW2. An obvious problem was that it involved the aircraft transmitting a carrier wave for perhaps 20 or 30 seconds and a delay while its position was calculated, so that when the pilot finally got his position it was usually where he was a few

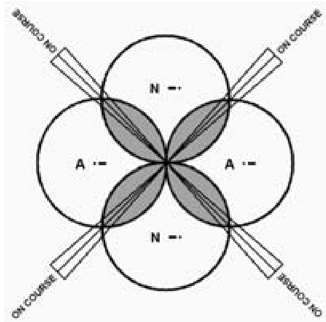

Figure 1. The Radio-range radiation pattern.

minutes ago. Perhaps at the relatively slow cruising speeds common in the 1930's (90–120 kts) it was not very important, but as aircraft got faster it began to matter. The biggest problem was that only one aircraft could obtain its position at a time and as air traffic developed this type of DF system could not cope with the ever-more frequent and numerous requests for position.

2. THE AMERICAN SITUATION. It was in 1920's and 1930's in the USA that the problems of accurate aerial navigation really came to a head. With its vast, and then relatively uninhabited spaces, aircraft were a real solution to the questions of how to send mail and people rapidly from New York to the mid-West and California. To navigate aircraft over these routes, a system of "aerial lighthouses" was set up, later replaced by radio beacons. The only crew on these flights was a single pilot who, flying manually, did not have time to operate radio transmitters or anything other than simple radio receivers. The emphasis was therefore placed on ground radio beacons that needed nothing but aural interpretation in the cockpit and this led to the introduction of "radio-ranges". These were radio beacons using antennas with controllable sharp nulls in their radiation pattern which could be used, in conjunction with suitable transmitter switching, to produce a pattern of Morse code "A"s (dit-dah) to one side of the required track, and "N"s (dah-dit) the other. When the aircraft was exactly on track they merged to give a continuous note. (See Figure 1.)

It was very simple to use – all the pilot had to do was to fly so that he heard the steady note at all times and he would eventually arrive overhead the beacon. Its utility was improved through the installation of marker beacons which permitted periodic position fixes to be made by producing an audio tone on a different frequency as the aircraft passed overhead. It was a receive-only system that could cope with any number of aircraft simultaneously and the use of frequencies in the 300 kHz band meant that it could be used at any altitude from ground upwards. It permitted flights in poor weather conditions and at night over long distances, and was an important factor in the spectacular development of civil air transport in the United States between 1930 and 1950. The radio-range (in contradistinction to airborne radio compasses and automatic direction finders) was the first system permitting establishment of fixed geographical paths that aircraft could follow in a positive and reliable manner. Because aircraft flying by radio-range signals could maintain assigned paths (within the accuracy of the system), the radio-ranges also made possible systematic air traffic control. By 1950, there were 400 operational civil radio ranges in the United States, serving over 60,000 miles (97,000 kilometres) of federal airways, with 600 more over the rest of the world. As was stated in an American document of the time, *"…the four-course range has a unique advantage – no special airborne receiver or instrumentation is required. All that the airplane requires is a simple communication receiver and headphone – the minimum radio equipment that an airplane would carry anyway. This feature endears the radio-range system especially to operators of small aircraft, which are equipped with the minimum of radio apparatus to save weight, space, and expense. The existing four-course ranges also provide an emergency navigation facility to larger aircraft that carry modern radio equipments. Thus, the airplane carries no equipment that is difficult to service, takes up a lot of space, weighs a great deal, and is expensive; all heavy and complex equipment is exclusively at the beacon on solid ground, which eases the problem of servicing and maintenance. With respect to simplicity and operational reliability, the system is far superior to all existing systems; airways that are provided with this system should be flyable with safety even at night and in fog and under all weather conditions."*

Development in Europe was somewhat slower, rather surprisingly considering that Otto Scheller, a German national, and Lorenz, a German company, were at the forefront of radio-range development. However, Germany took the European lead and by 1939 had established 14 radio-ranges with another two in Austria. In other European countries there were none, but during the war the American Forces established a number in the UK and on the mainland of Europe for their own use; these were left in place post-war and eventually formed the basis for a European airways network similar to that in the USA.

Perhaps the main problem with the MF radio-range was that it did not perform well in poor weather conditions with rain and thunderstorm static, and at night it was liable to sky wave distortion of the equisignal lanes at anything other than short ranges. Both these problems could be overcome by the use of VHF instead of MF and wartime electronic development had accelerated the use of VHF. VHF also made possible the extension of the radio-range principle to enable a ground beacon to provide accurate bearings automatically in any direction bringing about the VHF Omni-Range (VOR) beacon.

The new pulse transmission techniques enabled direct measurement of distance to a ground beacon, distance-measuring equipment (DME), which replaced the fixed and sparse distance-checking beacons with continuous distance-along-track information. The two together could provide all that was needed for the further development of airways, the beauty of it being, for the Americans, that it required no change in either their airways or air traffic control systems. They therefore went whole-heartedly for VOR/DME while retaining the radio-range for the time being while the new equipment was being developed.

Thus, by 1945, a considerable investment in point-source aids had already been made in the USA; their entire airways network depended on them and their transport pilots were well-trained in their use. The US method of flying point-to-point along airways spread rapidly into other parts of the world as commercial flying on a large scale expanded.

3. THE UK AND EUROPE.

Elsewhere the situation was quite different; there were no airways because civil air traffic did not warrant them. In Europe

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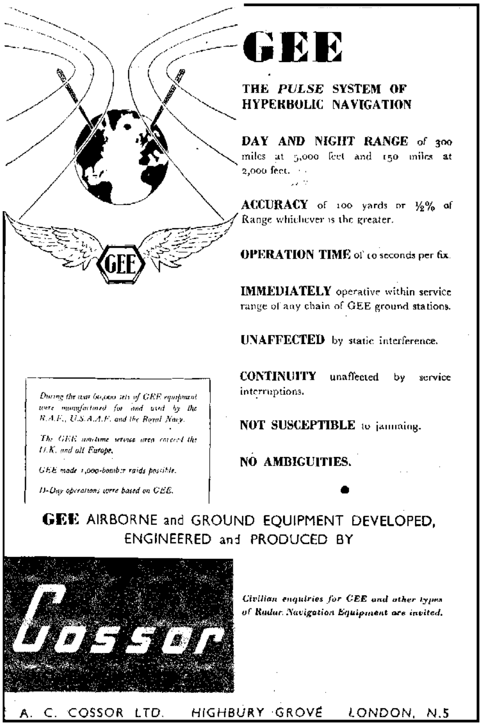

Figure 2. Cossor advertisement for GEE, 1946.

distances were much shorter and there was a close-knit network of railways that sufficed for these shorter distances. Lacking airways there was no need for centralised air traffic control; it was conducted from individual aerodrome control towers as required, often by visual signals since only the very largest civil aircraft carried radio. In the UK there was little development of radio navaids other than ground MF direction-finding (MFDF) stations and there were very few of those. This all changed during the war when it was realised that RAF bombers were not getting to their targets and in the absence of MFDF something better than sextants and dead-reckoning was necessary. The invention of the GEE system followed, the world's first operational hyperbolic area-coverage navaid (the American Loran-A came later). It was an enormous success and became the standard all-purpose radio navaid fitted to RAF aircraft and a large number of American aircraft as well. Even the Germans used it in their intruder aircraft and eventually copied it ("Bodentruhe").

GEE was seen in the UK to offer great advantages for civil aircraft in that it could be used as a basis for the newly proposed airways system for Britain and Europe. All that had to be done was to install the relatively few GEE chains required to cover continental Europe and airways could be drawn up and changed as necessary without any requirement for the re-installation of new navaids every time a change was made. Off-airways traffic could also use it just as accurately, unlike radio-ranges that were fairly useless away from airways. At the time most of Europe was devastated by war and the exact way in which civil air traffic could be re-established was difficult to see.

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Figure 3. VOR/ADF Bearing Indicator.

Figure 4. GEE MK. 2 Indicator Unit.

In the UK, knowledge of air traffic control methods and systems had been brought up-to-date rather forcibly by the effort of managing the very large numbers of aircraft that operated out of the UK 1943–1945 and personnel had become skilled in managing aircraft on random tracks. Without any real investment in civil aviation radio navaids to protect (the MFDF system centred on the Croydon airport watch office was thought to be the last word in sophistication in 1939) it could afford to think anew with the benefit of the new devices and equipment developed during the war and Cossor, the builders of GEE, were encouraged to promote it for civil use. (Figure 2.)

GEE, being a VHF system had no problems with sky waves or static interference. It originally used high HF channels around 22–30 MHz but the later GEE chains used true VHF channels between 40 and 80 MHz and all future proposals contemplated using this band. In principle, there was nothing to stop GEE going even higher and it could easily have been put into the aircraft VHF band in the 110–120 MHz segment that was eventually allocated for aviation radio navigation. Although it gave only line-of-sight performance and did not perform well at ground-level this was irrelevant at the heights used by aircraft. Only low-flying aircraft such as helicopters might have had a problem but in 1945 they were in their infancy and not seriously considered as transport aircraft. Anyway, it affected the VHF-based VOR/DME systems quite as much and it could not be considered a criticism of GEE alone. GEE also had the advantage of being completely free from ambiguities – that is, any particular combination of readings applied to one and only one position.

The real problem with GEE lay not in its basic concept but in its presentation – how it was interpreted by the pilot. The radio-range worked through a pilots' ears; he just needed a pair of headphones, and ADF/VOR were presented on simple meter and pointer displays that were easily followed. (See Figure 3.) The GEE that was available at the end of the war (Mk 2) needed much more work. In the first place, pulses had to be matched up manually on what was, on the CRT's of the day, a very dim display. (See Figure 4.)

GEE always needed a hood over the scope to see it properly except at night, and expecting a pilot to transfer his vision from that to the often brilliant sunlight outside the cockpit rapidly and frequently was just impossible. This point alone made it a non-starter for the "flying along GEE lines" idea that was much put about at the time, an idea that even led to the establishment of a special "London" GEE chain with its hyperbolic lines arranged to line up with the runways at the new Heathrow airport that was being built. The interpolation of another man in this chain, a navigator, who could afford to keep his head inside the hood all the time and give a pilot left-right directions was impracticable, introducing a time-lag that could lead the inexperienced into wild off-track excursions, as anyone who has ever tried to land an aircraft using the old BABS system will know. Then, assuming the pulses had been lined up properly, time-differences had to be read off by switching to a new time base, in three stages, and counting timing pips. Once the two counts had been obtained, a special chart was necessary to find the intersection of the two time difference lines. That gave the aircraft's position well enough, but it provided no indication, of itself, as to how to reach its destination. That had to be calculated, usually by further plotting on the chart, and the results conveyed to the pilot. It was a very roundabout system open to error. It meant a second man was essential, and although he could also act as co-pilot he was often an extra unwanted link.

The problem of having to refer readings to a map before usable guidance information could be obtained dogged area-coverage systems for a long time and there were many efforts to overcome it. Cossor Ltd, who had built most of the GEE receivers during the war, announced in 1947 a new "direct-reading" GEE set. This set, the Mk 3, was indeed a considerable improvement on the Mk2, being much smaller, but it still relied on human intervention to align the pulses on a CRT display. The "direct-reading" claim was made because, once aligned, the operator did not have to go through a series of counting time bases but just read out the time differences from two mechanical counters. This certainly eliminated counting errors but it still needed someone to line up the pulses. GEE also suffered from a problem inherent in all time-difference systems; its position-lines were not straight but hyperbolic and appeared as curved lines on a normal orthomorphic chart. The easiest way of using GEE was to fly down a hyperbola by keeping two pulses superimposed, but this resulted in a curved track over the ground. However, over short distances it was very nearly a straight line and "GEE approaches" could often be flown by using a hyperbola that ran straight down a runway.

But it was all too much for civil pilots who increasingly, in the late 1940's, were flying without a navigator. The introduction of airways in the UK in 1949, which meant flying to and from fixed points, and the ready availability of point-source aids, spelt doom for GEE which, failing take-up by civil aviation, remained a specialist military system and was eventually phased out in 1971.

4. DECCA NAVIGATOR. The UK authorities always maintained their faith in area-coverage systems and it was a marine navaid, Decca Navigator, that revived it. Invented by an American, Bill O'Brien, in 1938 it worked in not too different a manner from GEE by measuring time differences between synchronised transmitters. That said there were very significant differences in the frequencies used and the way timing was done. It used the low-frequency band 70–130 kHz and

Figure 5. Decca lane-indicating meters – Decometers. (1950)

although this eliminated problems with altitude it also meant that pulses could not be use for timing and instead phase comparison had to be used. At 100 kHz one cycle of phase is 10 microseconds, a distance of about 3 km, but since two transmitters were being compared the actual "lane width" of Decca was on average only half this, or 1·5 km. Although accuracy within this lane could be very high, 100 metres or better, any one measurement was repeated every lane and so there was an irresolvable ambiguity every 1·5 km. In 1948 Decca developed a method of overcoming it called lane identification, but it still did not totally overcome ambiguity, leaving residual ambiguities approximately every 12 km. Not a particular concern for mariners, but an aircraft might traverse one of these ambiguities every 45 seconds. Later, in 1960, Decca introduced yet another stage of ambiguity resolution specifically for aircraft ("zone identification") but it had limitations and also caused considerable complication in the Decca transmitter switching arrangements. Additionally, Decca had problems with signal reception in aircraft. In rain or ice cloud, static discharge from the airframe could prevent reception, and it was liable to night-time sky wave interfering with proper ambiguity resolution. Although it was an excellent system for mariners, and was widely adopted by them, in comparison with GEE it was not at all the right basic system for aircraft in spite of the enormous efforts made by Decca to reduce these drawbacks. This became the general opinion amongst practically everybody who had flown both systems.

Decca's real advantage was that it had much better presentation than GEE. In its simplest form it did not rely on CRTs but instead presented its results on circular meters, known familiarly in its early days as "gas meters". (See Figure 5.) As in GEE, an aircraft could home down a Decca hyperbolic line but using Decca it could be done by simply keeping a needle on a meter steady, just like ADF/VOR. A second lattice could be used as an elementary distance-to-go indicator by watching its needle wind down around a second meter. However, even so, it needed a knowledgeable pilot to set it up and something better was required. Decca realised this at an early stage and, in 1947, resurrected the old moving-map ideas that had first seen light in WW1 and had been used in WW2 for the Ground Position Indicator. By using one Decca pattern to drive a roller map vertically and a second one to drive a pen across it horizontally, the aircraft's position could be seen instantly and a trace left of where it had been. (See Figure 6) Airways and airfields were drawn on the map and the pilot

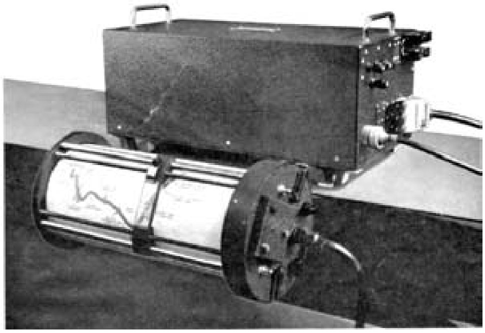

Figure 6. Early (1948) Decca roller-map.

could simply "fly the pen" along the desired track to his destination. An excellent idea and one that at the time could not be bettered, but a major problem was that the Decca lattice lines were hyperbolae and the rectilinear motion of the map and pen straightened them out, resulting in what was sometimes gross distortion of airways and features on the ground.

Many pilots never got used to the idea that an airway they knew was straight and of constant width appeared on the Decca map to be badly curved and of variable width. Decca did what they could to reduce these distortions by using complex second-order patterns but it was a problem unresolved until the digital computer appeared in the 1960's. Setting up this map was not simple, either. For any given route a roll of maps had to be assembled and provided there were no changes of route or diversions while airborne they worked quite well, but it all too often happened that operational circumstances made a change of route essential and there was no map to cover it. In addition, pens dried out and boxes of "keys" had to be carried. These "keys" were inserted into the map control unit to program the unit for the map in use, to be changed every time a new map was used. Moreover, at the end of each flight, the map rolls and keys had to be changed, resulting in Decca having to employ staff at the main airports to do this. Fortunately, flight density was far less then than it is now and they could just about cope at busy periods.

Originally, Decca's company policy, for obvious reasons, was that only the Decca Navigator system should be used as the navigation input to control this map display. In retrospect, this was a mistake. Decca were undoubtedly ahead of the field in aircraft map displays at the time and with all its shortcomings its roller maps were state-of-the-art. What they needed was a reliable navaid to drive them and this, for aircraft, the Decca Navigator was not. Had GEE, for instance, been used (it was still transmitting then) the many criticisms that "Decca only works in fine weather" would have vanished. The entire BEA fleet of Viscount 700s was experimentally fitted with Decca Mk 7 and the Flight Log and apart from the usual teething problems the main problem was the unreliability of reception of Decca signals in poor weather, just when it was needed.

Decca made a great effort to overcome this static discharge problem even to the extent of buying a company specialising in wick dischargers, but to no avail. It was not as if Decca did not have access to the GEE system; by the late 1940's Cossor had

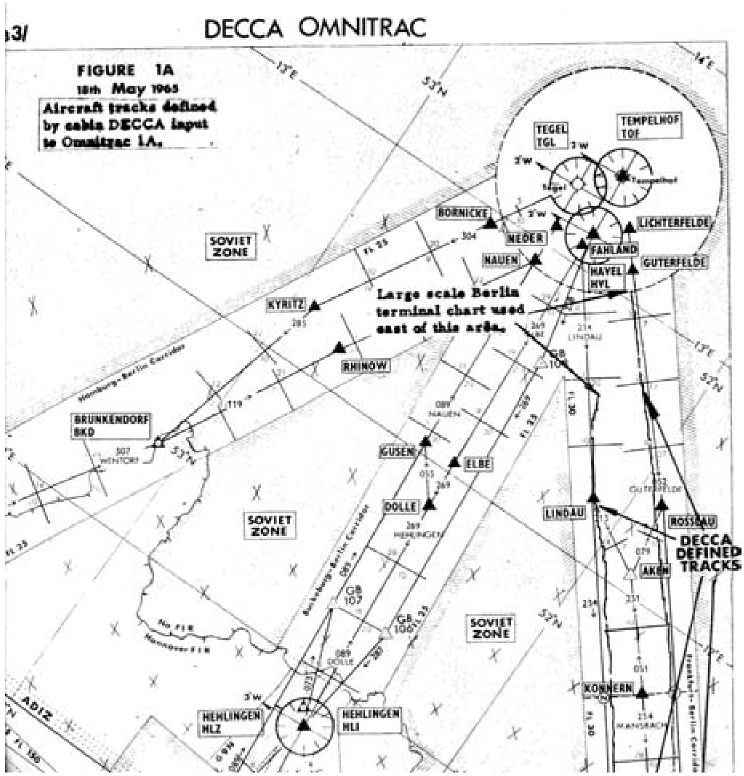

Figure 7. Decca Omnitrac map display. (1965)

given up hope of introducing it as a civil navaid and had gone on to other things, leaving Decca to buy up several of the major GEE patents. Unfortunately, Decca bought them not with a view to using them, but to prevent competition appearing. Decca engineers came up with a number of ideas for using the patents, amongst them one for introducing phase comparison within the GEE pulses so that similar accuracy to Decca could be obtained along with absence of ambiguity. That, combined with VHF's freedom from propagational disturbances, would have made an excellent navaid and its feasibility was later proven both by Loran-C, for which Decca built some of the first receivers, and, much later, GPS. Had that line of development been followed–and it was not beyond the technology of the 1950's to do so – there could have been an area-coverage aviation navaid of superlative performance by the early 1960's, a worthy opponent of point-source aids.

A major advance occurred in the late 1950's when the technology to build small digital computers appeared. In 1961 Decca publicised their Omnitrac, the first airborne digital computer for civil users. At last, the peculiarly distorted charts that were most pilots' impression of Decca disappeared, Omnitrac performing the hyperbolic-to-rectilinear conversion fast enough to cope with aircraft speeds. (See Figure 7)

This was a serious advance and was the first step in a series of other major improvements including left-right and distance-to-go indicators. Eventually, Decca tacitly admitted that the Navigator system itself was the weakness of its developments and dropped its insistence on it as the Omnitrac driver. VOR/DME, Loran-C, Doppler, INS and Omega were then all used at various times but many other much bigger electronics companies began building directly competitive equipment and Decca, having driven itself near to bankruptcy with its efforts to get the Navigator adopted, did not have the resources to compete. Decca eventually fell out of the avionics race and remained as a marine navaid until, in the 1990's, GPS swept all before it. The last Decca chain was closed down in March 2000.

5. THE AREA-COVERAGE BATTLE IN ICAO. In 1946, the COT Division of the International Civil Aviation Organisation (ICAO) met in Montreal to decide, amongst other things, the standardisation of a short-distance navigational aid to meet the needs of civil aviation. The United Kingdom pressed the claims of GEE with which there was considerable war-time operational experience. The United States advanced VOR as their contender. VOR, development of which had begun in 1937, had been designed as a replacement for the four-course radio-range but, at the time of the COT Meeting, no operational experience had been gained with it since it had been shelved during the war. The arguments for area-coverage were strong and since VOR provided only azimuthal guidance it was seen to be at a serious disadvantage with systems like GEE which gave full position fixing information over a wide area. Realising this, the Americans introduced the concept of adding DME to VOR – a combination of distance and bearing to give a 'fix'. It is often forgotten that VOR/DME did not originally emerge fully-fledged as a unified system; the addition of DME was very much an ad hoc decision, made during the actual meeting, solely to counter the GEE threat and without any idea about the specific equipment that would be used. However, the addition of distance measurement did not solve the restrictive problem that aircraft still had to fly to or from the VOR station. This handicap was the subject of another American promise: that a "course-line computer" would be developed for airborne use which would enable aircraft to fly in any direction across the radii of the VOR, thus giving much greater flexibility to the system and, in effect, turning VOR/DME into an area-coverage system. Some fourteen years after this meeting, by the time of the fateful 1959 conference, a course-line computer had still not been developed to the stage where it could be installed in scheduled airline aircraft and it had to await the emergence of the digital computer. Nevertheless, despite the advantages of GEE vis-à-vis VOR, the latter was accepted. The machinery having been thus set in motion, VOR became the approved International Short-Distance Navigational Aid at the 1949 Third Session of the Communications Division of what had by then become ICAO. It is interesting to note that the wording of the application standard which appeared in Annex 10 to the ICAO Convention, in respect of VOR, appears to show that there was no intention at that time to bring about a widespread application of VOR. The Annex stated:

> "2.2.1. In localities where conditions of traffic density and low visibility necessitates a short-distance radio aid to navigation for the efficient exercise of ATC, the standard aid shall be the VOR, of the C.W. phase comparison type, conforming to the standard contained in Part *1.3.4.*"

VOR having been standardised, the next step was to achieve similar official status for DME. This was the subject of prolonged ICAO discussion and, eventually, in 1953, the specification of a 1,000 MHz DME was written into the Annex. Despite US efforts to do so, however, DME was not accorded the status of a Standard but only that of a Recommended Practice. The position in 1953, then, was that VOR was the ICAO short-distance navigational aid with the recommendation that, where necessary, States should consider the addition of DME as a supplement to it.

In the years following the COT Division Meeting, the United Kingdom, maintaining its argument that area-coverage was essential, transferred its support from GEE to Decca. This was done because Decca, building on its solid marine base, had been developing it rapidly as an air aid and because, as already mentioned, it had re-introduced the technique of presenting information pictorially to the pilot. However, the United Kingdom move from GEE to Decca was a change of system but not of philosophy. It should be noted that UK support was officially for an area-coverage navaid and not specifically for Decca. It was thought improper for the Government to directly support any particular company and the fact that Decca was the only system that could support area-coverage, as it was defined at the time, was quietly ignored. British European Airways (BEA) had also always been convinced that an area coverage system was essential and in fact had been instrumental in persuading the UK Government of this, so, in 1952, it decided to equip its new Viscount fleet with Decca. BEA also pressed the advantages of such a pictorially presented system over those of point source aids, in the International Airline Transport Association (IATA) but unfortunately, most of its members were American airlines who had mainly their domestic routes in mind where there was no Decca.

It does not follow that because an aid has been officially recognised by ICAO, wide-scale implementation follows immediately. In 1955, for example, six years after it had been made a Standard, only 14 VORs had been deployed in Europe out of an estimated total requirement for 98. As would be expected, installations had been made much more rapidly in the United States where, by the same date, about 450 were being used to mark the airways. DME progress, however, was even slower. Outside America only three DME beacons, to the ICAO Standard, had been installed. Trials of the airborne DME System had been far from satisfactory; BOAC fitted two aircraft but were not enthusiastic about the results. Accordingly, BOAC decided to continue with the 200 MHz DME System–in effect the original war-time Eureka distance measuring equipment–on certain of their far eastern trunk routes to Australia.

Australia had begun to deploy 200 MHz DME on a wide scale and later made it a mandatory aid in that continent. This meant that all scheduled domestic aircraft in Australia were required to carry DME and the Australians accumulated through the years more operational experience with DME than any other administration in the world, including the USA. Further, the United Kingdom, as an earnest of its international good faith, spent well over half-a-million pounds in developing DME to the ICAO specification.

In America the story was much the same. Although 200 of the ICAO DME beacons were commissioned, no scheduled civil airline fitted any aircraft to use them. Mohawk Airlines undertook an evaluation of DME for the Government but gave up eventually in view of the very low serviceability attained. A cheaper and lighter version of the airborne equipment was produced and was fitted in a number of executive-type aircraft, but, in effect, the ICAO DME was merely a theoretical, as opposed to a practical, recommendation.

While all this was going on, Decca put a great deal of effort into their aviation equipment and went as far as to design a new long-range version of Decca, called Dectra, intended to provide track guidance for transatlantic aircraft between Scotland and Newfoundland. It also, in 1954, proposed a world wide coverage hyperbolic system called Delrac operating at VLF. Omega, which appeared some time later, was always suspected of illicitly using many of Delrac's ideas, which had been freely publicised, and indeed in 1968 Decca won a patents case in the US courts along these lines. All three systems, Navigator, Dectra, and Delrac, working on the same principles, could be combined in one receiver and so Decca was able to argue that an aircraft fitted with a Decca receiver could have world-wide navigational coverage combined with very accurate terminal guidance, features that could not be duplicated by any point-source aid. In addition, these features were to be displayed on its unique map displays although at this time Omnitrac had not appeared and Decca maps were still distorted.

The matter finally came to a head at a special meeting of the ICAO in Montreal in 1959, called to standardise short-range air navigation aids throughout the world. It was a vital conference; the size of the market and its potential was obviously enormous as civil aviation moved into the jet transport age. The US had decided well in advance that VOR/DME should prevail while most European countries were solidly in favour of area-coverage. Decca went to the expense of setting up a Decca Navigator chain in the New York area, and a Comet from Boscombe Down was flown over to give demonstrations, rated as "very successful" by Decca. Rather surprisingly, a large number of delegates from countries that had never previously taken any interest in air navigation suddenly appeared at the meeting. Countries like Nicaragua, South Korea, Bolivia and the like voted solidly in favour of VOR/DME, no doubt encouraged by the later-divulged US offer of free equipment. IATA, which a year earlier had decided that area-coverage had something to offer, now suddenly performed a volte-face and supported VOR/DME. It hotly denied that the maintenance of profitable routes to the USA was more important than mere navaids. An FAA flight-test report on Decca complained of its poor performance while omitting to state that much of its test area was outside the official coverage area of the New York Decca chain and they had not consulted Decca. This report was presented to the meeting in spite of British complaints and many years later its author admitted shamefacedly that he had been pressurised into it by very senior politicians. Angry British statements were made, followed by promised withdrawals by the USA, which never materialised, and so on. One senior American delegate, asked his opinion, said *"it is always a mistake to introduce a note of realism into proceedings such as these"*. The conference became a farce but the British delegation behaved well. Instead of walking out, they stayed to the end to see their system defeated by one vote. In Britain, after a minor flurry in the Press and a Parliamentary question or two, the affair subsided and was forgotten. VOR/DME became the standard navaid and the United States achieved its aim of protecting its own investment and incidentally got its fingers on a huge slice of the world market for navaids.

6. WAS THE UK RIGHT? The theoretical superiority of an idea does not guarantee its success. Point-source is admirable for the narrow purpose of controlling traffic along clearly-defined airways and does not need a computer to provide ease of interpretation. But when airways traffic proliferates the concentration of traffic over fixed points creates a collision risk unless it is rigidly controlled and then the very act of close control reduces the possible throughput of traffic. New airways can be introduced if there is airspace, but then new beacons are required. Nowadays, of course, computers have enabled point-source aids to be used virtually as area-coverage sources, although they still cannot overcome the serious loss of accuracy of bearing-type systems like VOR with increasing distance. In turn, this has led to the adoption of twin, or multiple, DME-type beacons as area-coverage sources so we now have de facto area-coverage systems using what were formerly point-source aids. Perhaps this is natural evolution enabling both sides to claim victory. The UK was, of course, perfectly right to support the concept of area-coverage but in the 1950's it was doing so from a theoretical viewpoint and could not demonstrate a genuinely competitive system in spite of Decca's claims. It was most unfortunate that Decca Navigator was not the right system for aircraft in an age before computers had appeared. It had ambiguity problems, it did not perform well in poor weather, and although its presentational methods were along the right lines they were sometimes awkward and difficult to use. Modern computer techniques have solved almost all of these problems and it is ironic that it is the USA itself that has now established a nation-wide network of Loran stations to provide area-coverage and support aircraft flying off-airways. With the advent of electronic screens and vast amounts of computer memory, it is now easy permanently to carry maps of every airway and airfield in the world and show any of them at a moment's notice.

Reverting to what was available in the 1950's, and with the benefit of hindsight, it is obvious the main difficulty was not the map displays but the Navigator system itself. No matter how good a map display, it cannot function when its basic input is faulty. For this reason, it now seems obvious that Decca should have abandoned promoting its Navigator for aircraft purposes and instead developed the GEE-like system with phase comparison for which it already held patents. That way, it would have capitalised on its lead in cockpit displays and been able to back them up with a solid input system. This combination might then have just been strong enough to hold the field long enough for the computer to rescue the distorted maps and give it a fighting chance against VOR/DME. However, it would have been a costly exercise needing Government aid that was conspicuously lacking for non-military private enterprises in the 1950's. Decca was never exactly a giant amongst companies and the income from its marine customers and its gramophone record business alone could not have supported such dramatic developments, although, again with the benefit of hindsight, there was one way it might have been worked. GEE was almost entirely financed by military subventions but in spite of internal RAF complaints at the time, it was not in fact costing a great deal in actual annual running costs. In 1957 the five UK GEE chains cost about £1M/year to run which Decca could probably have supported had there been no capital amortization involved. The UK Government could have offered to hand over GEE free of charge to Decca (Cossor having long withdrawn from the scene) and pay Decca to provide whatever GEE services the RAF still needed, on condition that Decca developed it as a civil aviation navaid with its own money.

A system compatible with the RAF's older receivers but offering considerably increased accuracy to new ones would not have been difficult to devise. This would have strengthened Decca's hand enormously and the RAF would probably have got its GEE services more cheaply. It is a course that would without any doubt have been taken today in an era of public/private partnerships, but we are talking of 50 years ago when such ideas were heresy.

However, another difficulty actually would very likely have killed this possibility at the outset. This was that the Decca management of the day was strongly against any diversion of attention away from the Navigator system. As an example, only slightly later, in 1960, a contract won by Decca to provide the US Navy with 400 Loran-C receivers, an extremely valuable contract, was described internally by a senior director as "betrayal" and staff instrumental in securing it were threatened with dismissal. Actually, this could have been built on leading to a potentially valuable re-orientation of Decca away from its insistence on the use of its Navigator system for aviation had it so wished. The purchase of GEE patents by Decca to prevent competition has already been mentioned. Given Decca's circumstances at the time this attitude by its management is perhaps understandable; they had a large privately-funded investment in the Navigator and wanted to capitalise on it further by obtaining the large additional user base offered by aviation. However, what is even now difficult to understand is why its basic unsuitability for aircraft took so long to be understood by them. It was not for lack of the right advice; Decca had at one time five aircraft of its own flying its systems and the shortcomings of Decca were well reported both by their crews and by those of the several airlines who temporarily flew Decca. Perhaps it was yet another case of a forceful Managing Director who had no first-hand experience of the problems, imposing his will on subordinates in spite of contrary evidence. It has happened before and will happen again.

That said, and even if that course had been impossible, Decca could have made much more of its cockpit displays in another way. Had it, like Cossor with GEE, decided earlier that the battle to establish the Navigator was too difficult, it could have re-directed the large amounts it poured out trying to force the Navigator through towards display development. Once it did get around to taking that decision in the 1970's, almost coincidentally with the departure of its original Managing Director, its aviation business started to do quite well – but unfortunately it was all a bit too late and by then it had missed the boat.

7. WHAT IF……?

The vote at Montreal was lost by only one vote. Had it been gained the formal position of ICAO would have been that "an area-coverage system" would have become a "Standard". Although this vote was widely seen as a direct battle between Decca and the VOR interests a win would not necessarily have resulted in Decca itself becoming the standard aviation navaid. No doubt other "area-coverage" navaids would have appeared overnight; at the time Loran-C was just appearing and it is extremely likely the USA would have begun campaigning for its adoption in preference to Decca. In fact, Loran-C had many advantages for aircraft over Decca because it was designed from the outset as a medium/long-range navaid without the ambiguity problems Decca had. Decca knew all about Loran-C, having designed one of the first automatic Loran-C receivers for the US Navy, and it had flown its Loran-C receiver at very nearly

Mach 1, admittedly by accident, during trials aboard an early RAF Vulcan aircraft. As a result, and in spite of considerable internal opposition, Decca began development of a private-venture Loran-C receiver for the RAF as early as 1961 (the ADL-21), the forerunner of a long line of successful military and civil Decca Loran-C receivers that persisted under various names until the 1990's.

Had Loran-C emerged as the front-runner for the area-coverage stakes, therefore, it would not have been at all difficult for Decca to switch to Loran and drop the Navigator system as the input for its map displays. In fact, Loran-C was made one of the very first inputs to Decca's Omnitrac computer and a rectilinear map display driven by Loran-C alone was demonstrated in the USA in 1963. Decca-designed Loran-C receivers driving Decca map displays were in use by the US Forces in Vietnam in 1967. Today, Loran-C, in its new guise as e-Loran, has been resurrected and is being promoted as a fall-back system for GPS, using, of course, a map display. New companies have emerged to promote it, while the Decca Navigator Company itself has long gone. It is to be hoped that if they are successful, the debt they owe to the pioneering work of Decca will be acknowledged. Whatever its modern name, area-coverage has arrived, rather later than it need have done, perhaps.